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WELCOME



When it comes to understanding loneliness, music's pretty much got it covered. From The Beatles to Bill Withers, and Roy Orbison to Radiohead, some of the greatest songs in modern history were written to express and relieve the pain of being alone. Science, it seems, has a bit of catching up to do.

We've known for a long time that isolation is bad for us. Accounts of prisoners placed in solitary confinement and questionable

experiments revealed the strange ways that extreme loneliness warps the brain. Meanwhile, large-scale analysis of the impacts of loneliness have shown that the chronically lonely tend to have higher blood pressure, are more likely to suffer from dementia and have weakened immune systems. In the long term, being lonely is worse for you than smoking 15 cigarettes a day. We know that loneliness is deadly, but what we don't understand is how isolation affects us so fundamentally that it changes us at a cellular level.

This is a problem. It seems like a loneliness epidemic is looming across the western world, despite social media and the internet making it easier to connect to each other. In the UK, 1 in 10 people report that they feel too lonely; over half of parents say that they've had problems with loneliness; and Childline says there has been a 10 per cent rise in calls from children suffering from loneliness. To shed light on the issue, this year the BBC is commissioning its own research and Radio 4's *All In The Mind* will be airing a series of programmes based on loneliness at different stages of life. On p48, Moya Sarnier investigates how loneliness hurts us, and what science can do about it.

Daniel Bennett

Daniel Bennett, Editor

IN THIS ISSUE



SIMON CROMPTON

We're all stressed these days. Simon, science journalist and former health editor for *The Times* and *The Daily Telegraph*, shows us how to take control. → p62



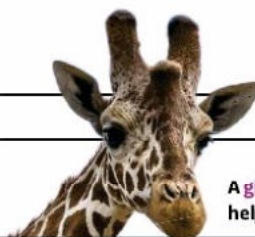
HELEN CZERSKI

Physicist and BBC presenter Helen has been travelling the world investigating the science of temperature. This month, she reveals some of its surprising effects. → p70



MOYA SARNIER

Health and science journalist Moya has been investigating why loneliness is on the rise, how it hurts us and what we can do to help those caught in its grip. → p48



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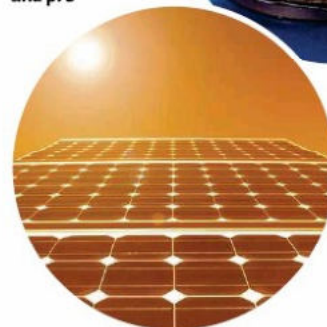
Polar bears and grizzlies can mate to give birth to grolar bears → p58



You can make a battery with 2p coins. Turn to our home experiments supplement between p74 and p75



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PLUS: DIY science

To celebrate British Science Week, try out some of our fabulous home experiments! Find them between pages 74 and 75.



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MORE FOR YOU

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SPECIAL ISSUE



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This special edition from the *BBC Focus* team takes you on a thrilling trip to the deep oceans, the centre of the Earth and outer space. buysubscriptions.com/focuscollection

EYE OPENER

Saharan snow

AÏN SÉFRA, ALGERIA

Not even the Sahara desert is safe from winter's icy tendrils. On 7 January, the dunes near the northern Algerian town of Aïn Séfra were blanketed with snow, which lay up to 40cm deep in some places.

"In the Sahara, temperatures at night can drop below freezing, but the air is usually too dry for precipitation," says Amanda Maycock, associate professor in climate dynamics at the University of Leeds. "In early January, a cold front from a weather system over the western Mediterranean Sea extended southwards over Algeria. This region of cold, dry air met another sector of warmer, moist air, creating the perfect conditions for snow."

Wintry weather in the northern Sahara is rare, but not unheard of – this is the third time snow has fallen in the region in nearly 40 years. Pictures on social media showed locals sliding down the snow-clad slopes on their stomachs. But the fun was short-lived: most of it had melted away by the end of the following day.

PHOTO: GEOFF ROBINSON/SHUTTERSTOCK





EYE OPENER

Through the looking glass

**RICHARD F CARIS MIRROR
LABORATORY, UNIVERSITY
OF ARIZONA, USA**

This picture shows the 'raw' glass that will eventually form one of the mirrors for the Giant Magellan Telescope (GMT) at Chile's Las Campanas Observatory.

Due to commence stargazing operations in 2025, the finished 'scope will have seven 8.4m mirrors that combine to give it an effective aperture of 24.5m. This enables the GMT to produce infrared images that are 10 times sharper than those captured by the Hubble Space Telescope.

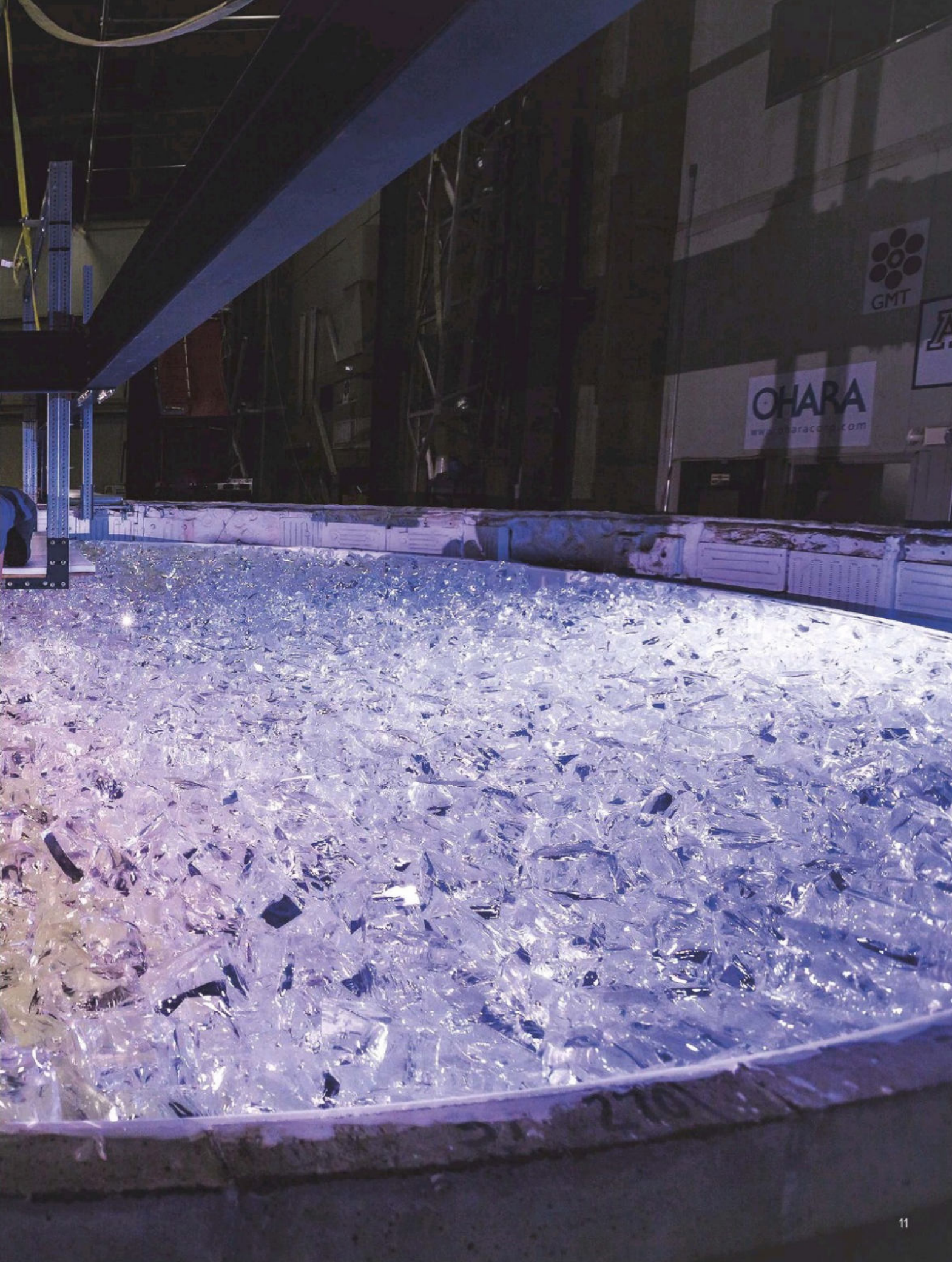
That level of optical precision can only be achieved through the use of high-quality materials and an exacting production process. Here, blocks of low-expansion E6 glass made by Japan's Ohara Corporation, weighing a total of 17,481kg, have been placed inside a hexagonal mould and are about to be heated to 1,165°C in a giant furnace that spins at 5rpm.

The glass will take around four hours to melt and settle into the mould, after which the furnace will rotate more slowly as the glass is carefully cooled over the course of three months.

Once this stage is complete, the mirror will be ready for shaping and polishing.

PHOTO: GMT CORPORATION







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MESSAGE OF THE MONTH

Eat fast, die young?

I'm a 45-year-old fast eater. I always have been, and I suspect it was linked to having older brothers and 'racing' to finish. In the Christmas issue, a study showed a link between fast eating and heart issues (p21). Is this because of how the body's digestive system works, or is it linked to fast eaters being 'fast' in other aspects of life, which has a negative impact, because of work, stress, anxiety, etc? For the record, while I am a fast eater, I'm generally pretty chilled in most other aspects of life!

Pete Starr, via email

➔ Thank you for getting in touch and thanks for reading the magazine. The study in question was only preliminary, so there are not really any concrete conclusions yet. The team found that fast eaters were more likely to develop metabolic syndrome – see here: nhs.uk/conditions/metabolic-syndrome

They think that this is because when people eat fast, they tend not to feel full. This means they are more likely to overeat, which makes them more likely to be overweight. Eating quickly also causes bigger glucose fluctuations, which can lead to insulin resistance and eventually type 2 diabetes.

– Jason Goodyer, commissioning editor

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a stylish **Nuu G3 smartphone**. It features an elegant edge-to-edge curved screen, octa-core processor, 4GB of RAM and facial recognition for security. It also comes equipped with dual rear cameras that keep moving objects in sharp focus. nuumobile.com



PHOTOS: GETTY X2



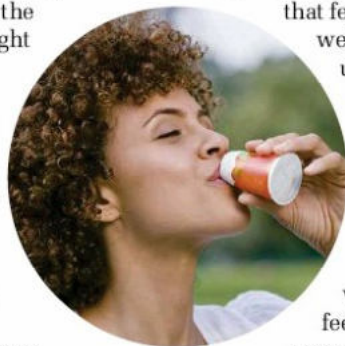
Gut feeling

I enjoyed your article on microbiomes and the effect they play in your health (February, p24). I've always been pretty healthy and active, and for the last 25-plus years I've eaten an ovo-lacto-pesco diet have and have reduced milk consumption to a minimum. I've always exercised, and before my kids were born I was a busy personal trainer. For the last six years I've taught group fitness in several different formats. See, I'm pretty healthy!

During last year's school summer holidays, (yep, I teach performing arts and dance at my kids' school) I picked up some extra group fitness classes. I was running from class to class and not preparing snacks, so I found

myself cruising to a big fast food chain since it was close and convenient. A small fries and a smoothie – how bad could that be, right? BAD! My belly started to bloat, I started to feel tired and 'off'. Even my daughter commented that my belly looked bloated. I looked pregnant!

It was not vanity that drove me to look for a solution but my loss of that feeling of balance and wellbeing. I just wasn't used to feeling this awful. I did some looking around and I found a probiotic that had some good reviews so I decided to give it a try. Within a week I was starting to feel better, my energy was returning, bodily functions were becoming regular and I was starting to feel like my old self again. The



directions said to take one capsule in the morning and one in the evening but I found that I had way too much energy to sleep well at night if I took it then. I know it says in the column that you aren't convinced by these kind of supplements, but I like my probiotics. Thanks for continuing to spread the word, hopefully it helps someone else get their balance.

Natasha Starbuck-Smith, via email

Get to Mars

Your recent articles about ice on Mars and NASA's nuclear reactors (February, p18 and p22) took me back to the 1990 film *Total Recall*. Perhaps we need Arnie to use the reactors to melt the ice and create a breathable Martian atmosphere? Just a thought...

Neill Harriild, via email

Arnie! We need you to help us colonise Mars!

Whatever floats your bloat

As a sufferer of eczema and asthma, I read Michael Mosley's column about the links between the microbiome and allergies with great interest (February, p24). I am going to try including more fermented foods and fibre in my diet in an attempt to ease the symptoms, but am somewhat concerned about the effect this may have on my stomach. I often feel bloated and gassy after meals, especially ones heavy in fibre.

Danny Burgess, via email

☛ According to Prof Tim Spector, a genetic epidemiologist, being gassy is a good sign that your gut bacteria are in rude health. As for a solution, we're not sure what to suggest other than a gas mask. We'll look into it.

— Daniel Bennett, editor



PHOTO: ALAMY

BBC FOCUS

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DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

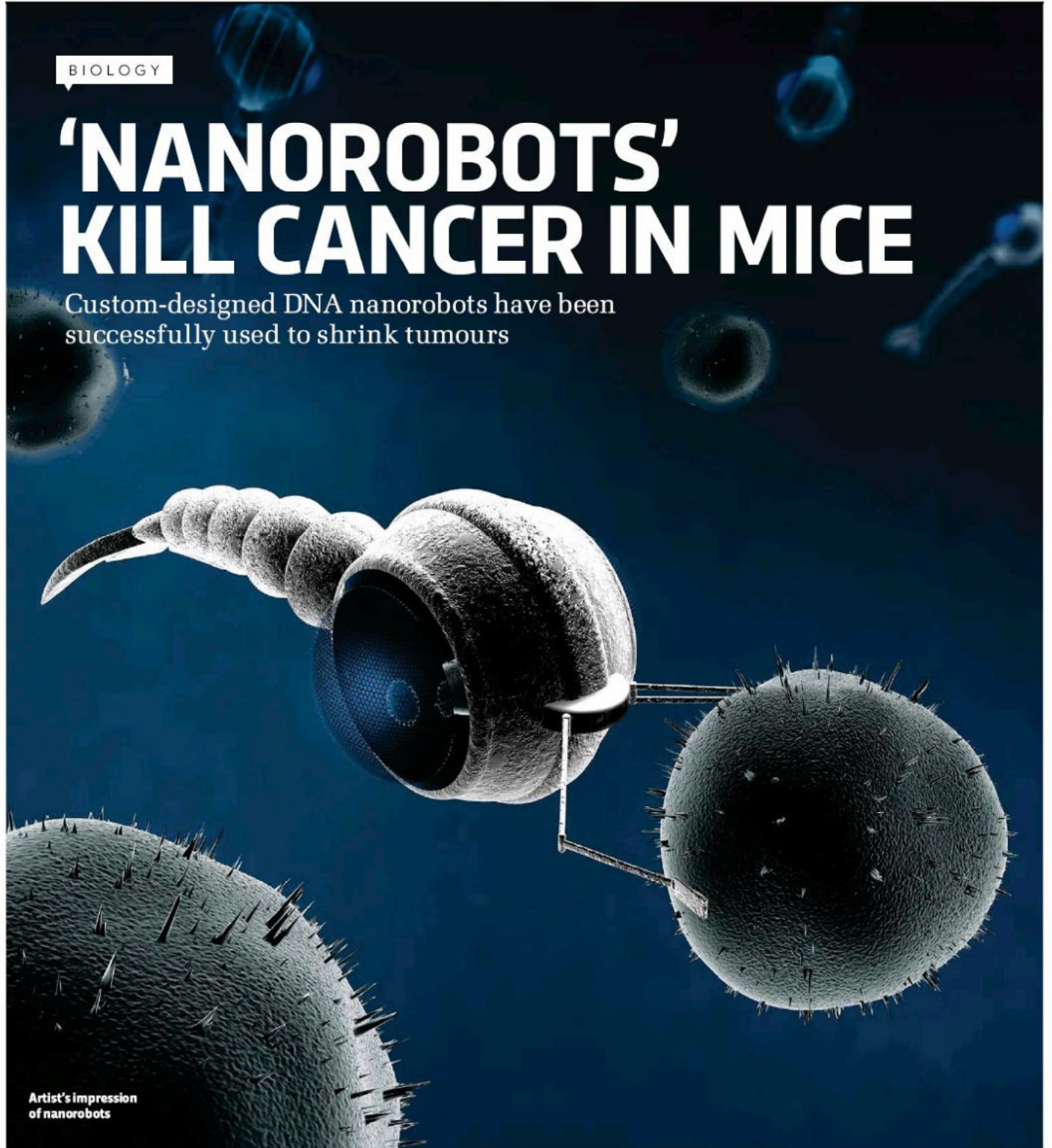
MARCH 2018

EDITED BY JASON GOODYER

BIOLOGY

'NANOROBOTS' KILL CANCER IN MICE

Custom-designed DNA nanorobots have been successfully used to shrink tumours



Artist's impression
of nanorobots

“WE HAVE DEVELOPED
THE FIRST FULLY
AUTONOMOUS, DNA ROBOTIC
SYSTEM FOR A VERY PRECISE
DRUG DESIGN AND TARGETED
CANCER THERAPY”

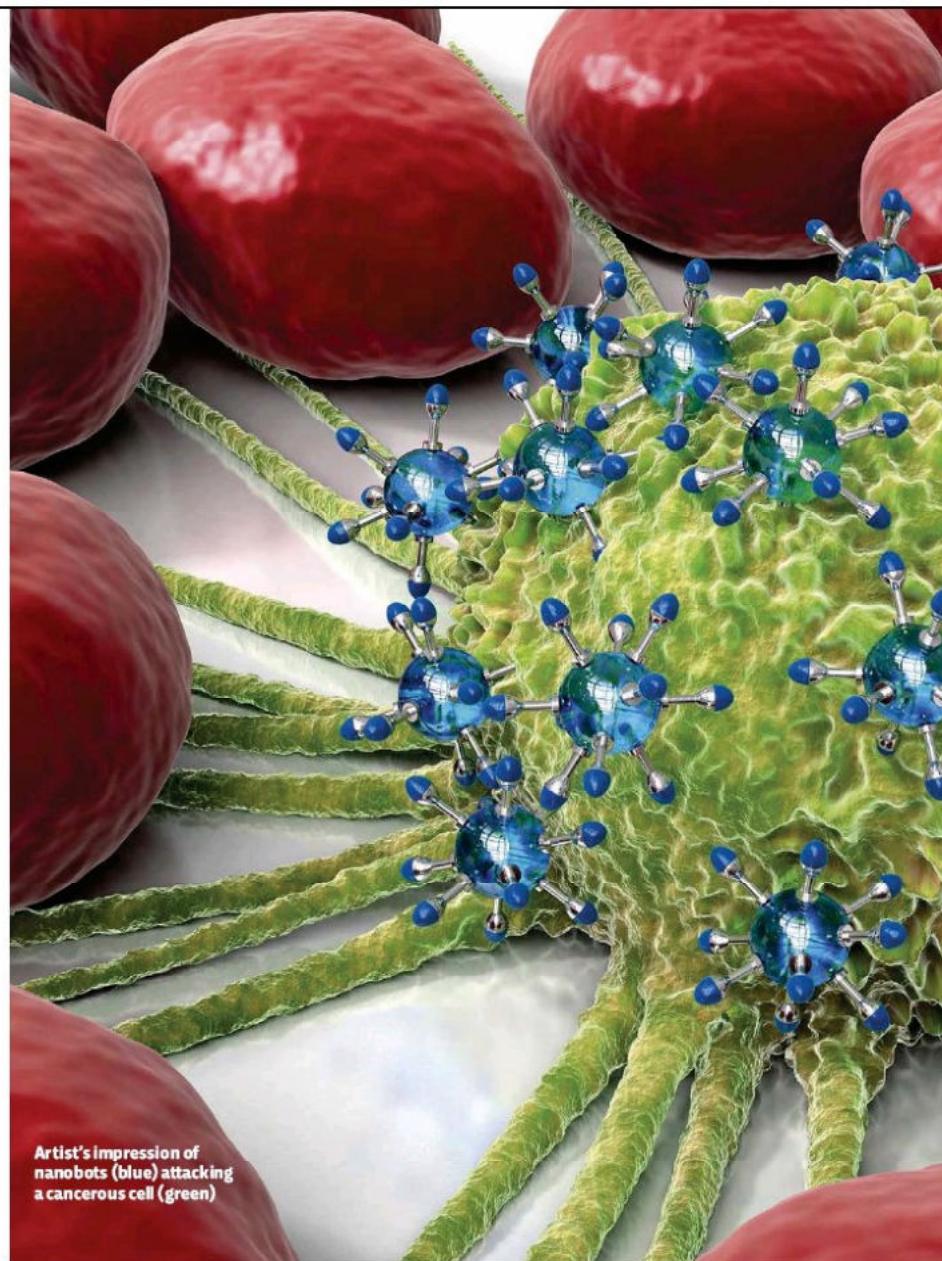
In a world first, researchers from Arizona State University and the Chinese Academy of Sciences in Beijing have used DNA ‘nanorobots’ to kill cancerous cells by cutting off their blood supply.

“We have developed the first fully autonomous, DNA robotic system for a very precise drug design and targeted cancer therapy,” said Prof Hao Yan. “Moreover, this technology is a strategy that can be used for many types of cancer, since all solid tumour-feeding blood vessels are essentially the same.”

The nanobots were made from flat, rectangular DNA sheets, 90 x 60nm in size. Thrombin, a blood-clotting enzyme, was attached to the surface. When delivered to the surface of a tumour, thrombin clots the blood within the vessels that feed the tumour, stems the blood flow, and kills the cancerous tissue.

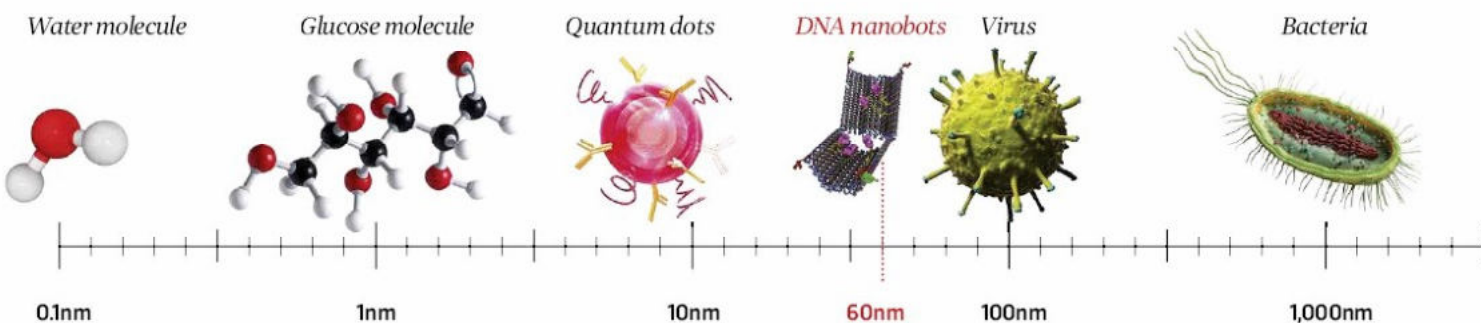
Another substance, called a DNA aptamer, was then attached to the nanorobots’ surfaces. When an aptamer comes into contact with a cancerous growth, it binds with nucleolin, a protein found on the surface of tumours and not on healthy cells, allowing the bot to deliver the thrombin.

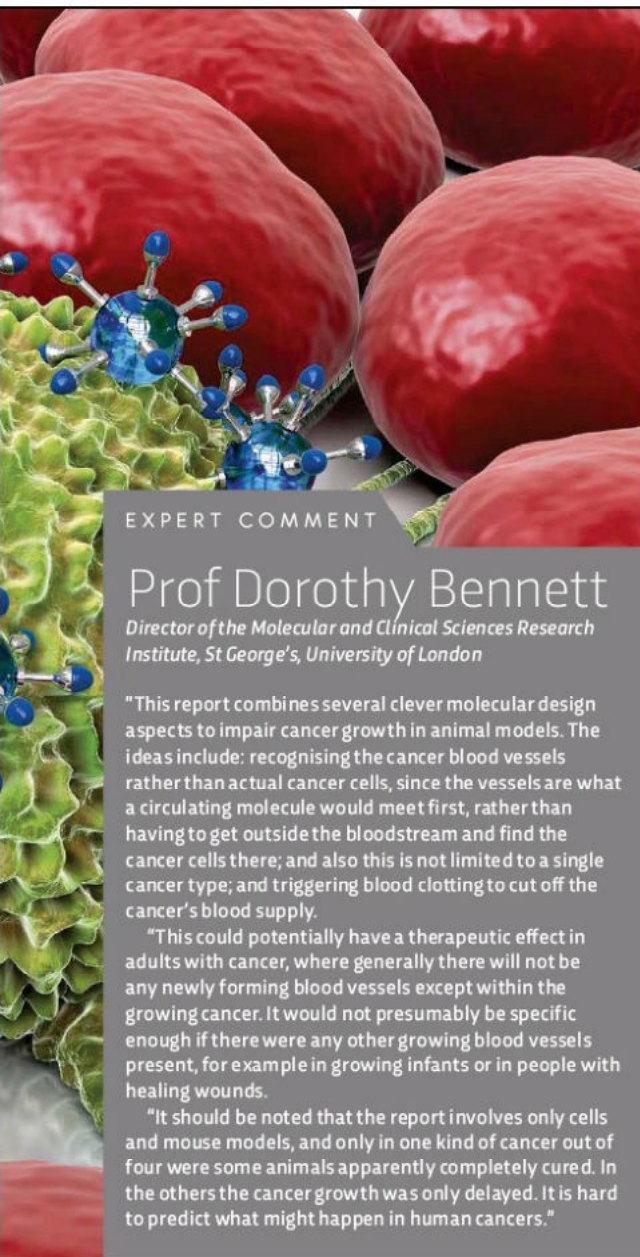
When given to a mouse that had been injected with human cancer cells, the bots travelled throughout the bloodstream, homed in on the



SIZE SCALE (width)

Electron microscope





EXPERT COMMENT

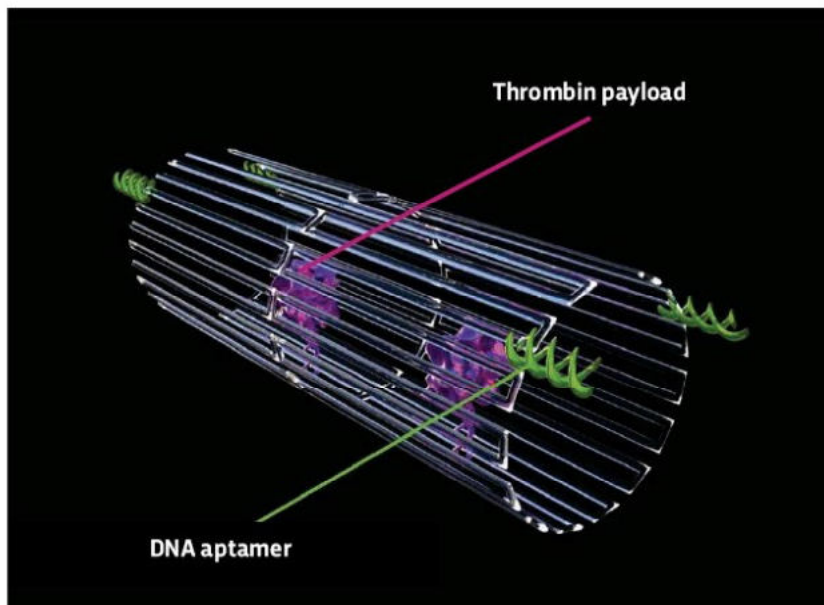
Prof Dorothy Bennett

Director of the Molecular and Clinical Sciences Research Institute, St George's, University of London

"This report combines several clever molecular design aspects to impair cancer growth in animal models. The ideas include: recognising the cancer blood vessels rather than actual cancer cells, since the vessels are what a circulating molecule would meet first, rather than having to get outside the bloodstream and find the cancer cells there; and also this is not limited to a single cancer type; and triggering blood clotting to cut off the cancer's blood supply.

"This could potentially have a therapeutic effect in adults with cancer, where generally there will not be any newly forming blood vessels except within the growing cancer. It would not presumably be specific enough if there were any other growing blood vessels present, for example in growing infants or in people with healing wounds.

"It should be noted that the report involves only cells and mouse models, and only in one kind of cancer out of four were some animals apparently completely cured. In the others the cancer growth was only delayed. It is hard to predict what might happen in human cancers."



DNA aptamers on the nanobots attach to cancerous cells, enabling the bots to deliver their lethal payload to a cancerous tumour

PHOTO: SCIENCE PHOTO LIBRARY, JAS ON DREES

tumours, and began working within hours.

Of the eight mice treated for melanoma, three showed complete regression of the tumours and the median survival time was doubled to 45 days. The team also tried the technique on breast, ovarian and lung cancers.

"I think we are much closer to real, practical medical applications of the technology," said Yan. "Combinations of different rationally designed nanorobots carrying various agents may help to accomplish the ultimate goal of cancer research: the eradication of solid tumours. Furthermore, the current strategy may be developed as a drug delivery platform for the treatment of other diseases by modification of the geometry of the nanostructures, the targeting groups and the loaded cargoes," he added.

Optical microscope

Unaided eye

Cancer cell

Human hair

40,000 DNA nanobots would fit on this full stop

Baked bean

Tennis ball



10,000nm

100,000nm

1,000,000nm

10,000,000nm

100,000,000nm



Certain ant species have powerful antibiotics on their bodies

MEDICINE

ANTS COULD HELP US CREATE THE NEXT GENERATION OF ANTIBIOTICS

It looks like humans may have an unlikely ally in the fight against antibacterial resistance: ants. Researchers at North Carolina State University have found that some species of ant possess powerful antimicrobial agents that protect them from disease.

The finding could lead to the development of powerful new antibiotics to replace the current generation of medicines that are becoming less effective as microbes evolve resistance.

The team removed the concoction of chemicals that coats the ants' bodies and introduced this to a slurry of bacteria. They then compared the growth of the bacteria in the slurry to bacteria in a control group.

Of the 20 species tested, 12 had some sort of antimicrobial agent on their exoskeletons. "One species we looked at, the

thief ant (*Solenopsis molesta*), had the most powerful antibiotic effect of any species we tested – and until now, no one had even shown that they made use of antimicrobials," said Dr Adrian Smith, who co-authored the paper. "Finding a species that carries a powerful antimicrobial agent is good news for those interested in finding new antibiotic agents that can help humans."

The researchers remain optimistic, but state that further tests need to be carried out. "Next steps include testing ant species against other bacteria, determining what substances are producing the antibiotic effects – and whether ants produce them or obtain them elsewhere, and exploring what alternative strategies ants use to defend against bacterial pathogens," said Smith.

ARCHAEOLOGY

ARCHAEOLOGISTS UNEARTH 'WORLD'S OLDEST CRAYON'



The Mesolithic crayon is sharper on one end, which suggests it was used for drawing or colouring



It seems like colouring in is a truly ancient pastime. An archaeological dig at a site near Scarborough, North Yorkshire, has unearthed what is believed to be a 10,000-year-old 'crayon' made from red ochre, a type of clay consisting mainly of ferric oxide.

The area in which the dig took place was already known to be rich in Mesolithic art. A pendant dug up in nearby Star Carr in 2015 is the oldest such object ever discovered, while a large number of headdresses made from red deer antlers have also been found in the area.

Now, a joint team from the University of York's departments of archaeology and physics has been responsible for locating and unearthing the new object, found preserved in peat. It's a naturally occurring pebble, measuring 22mm long by 7mm wide, whose end appears to have been sharpened to a point – as it would be if it had been used for painting on cave walls or on animal skins.

"Colour was a significant part of hunter-gatherer life and ochre gives you a very vibrant red colour. It was important in the Mesolithic period and seems to have been used in a number of ways," said lead author Dr Andy Needham. "For me, this is a very significant object and helps us build a bigger picture of what life was like in the area. It suggests it would have been a colourful place."

IN NUMBERS

25

The weight, in kg, of fish estimated to be eaten by an adult bottlenose dolphin in a single day.

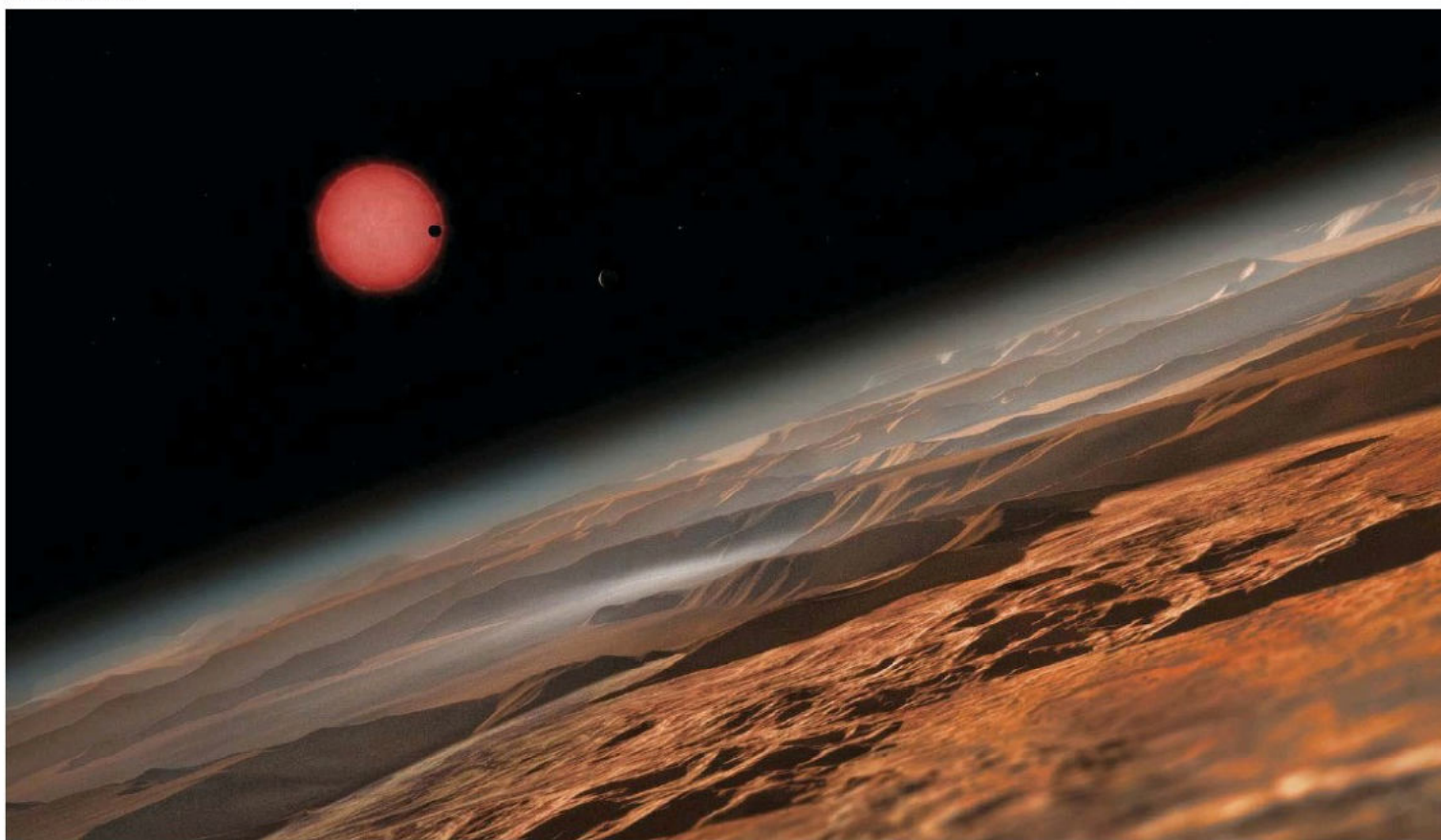
68

MILLION

The amount of mercury, in litres, that could be released into the atmosphere by the thawing of permafrost in the northern hemisphere, according to a new study by the US Geological Survey.

50,000

The number of genomes of people suffering rare diseases that have so far been sequenced by the NHS's 100,000 Genomes Project, which launched in 2012.



SPACE

HUBBLE REVEALS PLANETS WITH SIGNS OF SURFACE WATER IN TRAPPIST-1 SOLAR SYSTEM

Artist's impression of the TRAPPIST-1 dwarf star, as viewed from one of its planets

Three planets discovered last year could have liquid water – the key to life as we know it – sloshing around on their surfaces. The planets sit in the ‘Goldilocks zone’ of TRAPPIST-1, an ultra-cool dwarf star located 40 light-years from Earth in the constellation of Aquarius.

In total, four planets in the TRAPPIST-1 system orbit within this habitable zone, where the temperature’s just right for liquid water, and life, to exist. Astronomers searched all four planets for a hydrogen-rich and cloud-free atmosphere, which would indicate that the planets are likely to be gaseous, like Neptune. This type of atmosphere was only found on one of the four planets. The other three lacked hydrogen in their atmosphere, meaning they could hold surface water, just like Earth.

“This discovery is an important step towards determining if the planets might harbour liquid water on their surfaces, which could enable them to support living organisms,” said lead researcher Julien de Wit, from the Massachusetts Institute of Technology.

The researchers used the Hubble Space Telescope to measure light emitted from the star TRAPPIST-1 as it passed through each of the planets’ atmospheres. As light interacts with atoms and molecules in the planets’ atmospheres, slight changes occur in its distribution of frequencies, or spectrum.

By studying these changes, the researchers were able to determine some of the chemicals present in the TRAPPIST planets’ atmospheres.

A few different possibilities exist as to what kind of atmospheres these planets might have, but more powerful telescopes are needed to help us understand more.

“The next generation of telescopes – including the James Webb Space Telescope – will allow us to probe deeper into their atmospheres,” said lead author Prof Michael Gillon, from the University of Liege, Belgium. “This will allow us to search for heavier gases such as carbon, methane, water, and oxygen, which could offer biosignatures for life.”

WHAT IS TRAPPIST-1?

TRAPPIST-1 is a dwarf star that’s orbited by seven planets. It’s the solar system astronomers have found so far that best resembles our own.

With its hospitable temperatures and the possibility of water, it could also be the best chance we have at finding life outside the Solar System.

BIOLOGY

NAKED MOLE RATS REVEAL CLUES TO CANCER-FREE AGEING

The long, cancer-free lives of naked mole rats are intriguing. These rodents can live for up to 30 years, much longer than most animals of their size, and are resistant to many age-related diseases. Now, researchers from the University of Rochester have revealed a clue to these animals' remarkable longevity.

The team wanted to find out if naked mole rats have evolved to eliminate cellular senescence: a mechanism that prevents damaged cells from dividing out of control. Senescence is a mixed blessing, because while it protects against cancer, it also accelerates ageing.

"In humans, as in mice, ageing and cancer have competing interests," said lead author Prof Vera Gorbunova. "In order to prevent cancer, you need to stop cells from dividing. However, to prevent ageing, you want to keep cells dividing in order to replenish tissues."

Scientists have already tried to reverse the ageing process in mice

by removing senescent cells, and it worked – the mice became less frail.

This suggested that eliminating senescence might be the key to longevity, one which naked mole rats might already be employing.

Unexpectedly, the researchers found that naked mole rats do exhibit senescence but it doesn't work in the same way it does in mice. Senescence in mice permanently stops a cell from dividing, but the cell continues to metabolise. Naked mole rats, however, are able to strongly inhibit this metabolic process, resisting ageing effects. "It seems small," said Gorbunova, "but maybe it's what's really important."

Gorbunova and her team will continue to study these animals in the hope of finding a way keep us healthy into old age. "By studying naked mole rats and other long-lived mammals, we can find something to borrow to improve human health," Gorbunova said.



Naked mole rats inhabit burrows in the deserts of eastern Africa. They have an intriguing social structure, which is similar to that seen in ant or bee colonies

THEY DID WHAT?!



ORCA TAUGHT TO SPEAK

What did they do?

A team of researchers at the University of St Andrews taught Wikie, an orca based at Marineland Aquarium in Antibes, France, to imitate human speech.

What can she say?

The researchers picked words that were initially unfamiliar to Wikie. But by copying a trainer, she was able to say "hello" and "bye bye", and count to three. And she's a fast learner too – she often spoke the words correctly on her first try.

Why did they do it?

It's known that orcas in the wild have calls that are specific to their own pod, and when captive orcas are moved, they change their call to fit in with their new companions. The researchers wanted to show that the animals learn these new calls by imitating the sounds that they hear.

"If you look to the human brain for inspiration, it's very impressive"

Devices that mimic synapses – the junctions between neurons – could help us to produce more powerful computers. Physicist Dr Mike Schneider describes how he's building them

What is the idea behind creating an artificial synapse?

When you have a connection between two neurons, whether or not one triggers the next is determined by the synapse. This mechanism is believed to be responsible for things like memory. Lots of neurons are connected and the strength of their connection is varied by synapses. We wanted to see if we could make physical devices that match that, as opposed to the transistors and switches used in traditional computing architecture. If you look to the human brain for inspiration for computing, it's very impressive: you have 100 billion neurons and 100 trillion synapses, and yet it consumes just 20 Watts of power. And it excels at tasks that our modern computers, which are fantastic at multiplying and dividing numbers, don't do very well.

How did you build an artificial synapse?

The structures we have are based on niobium, a metal, with the synapse itself made from silicon and nano-clusters of manganese. We're running everything at 4 Kelvin [-269°C], the temperature of liquid helium. When you get

niobium cold, it becomes superconducting so has zero resistance to electric current.

How closely does this mimic the human brain?

Our system is based on something called a 'Josephson junction'. These are made by taking a superconductor and making a break in it using an electrical insulator. There are all kinds of interesting properties about them, but people have proposed that they could be used as an artificial neuron element because they produce a voltage surge that looks like the spike at a synapse, except it's much faster and in lower energy. These artificial synapses could be put into machines modelled after the brain.

How could such 'neuromorphic' computers be used?

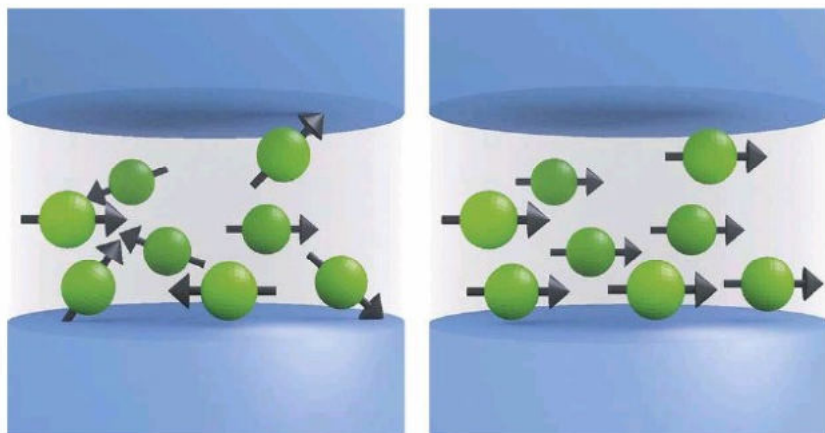
We are living in very exciting times where computing is concerned, with artificial intelligence and machine learning. Within the latter, you have algorithms written in software starting to solve problems that have traditionally been very difficult, like image recognition or language translation. These have a large 'state space' – the number of possible solutions to a problem. For image recognition, that's roughly the



ABOVE: Nerve synapses at work in the human brain

BELOW: Algorithms can make disordered artificial synapses function in a more orderly fashion

number of all possible pixel configurations, which is far too large to calculate explicitly. Over the past few years, deep 'neural networks' have made huge in-roads. What if we could make hardware that could run these algorithms sort of natively? The operations in the algorithm map well to neurons and synapses, so if you make a more efficient implementation, you can attack more complex problems.



INTELLIGENT MEN

Men that score higher on IQ tests – especially those testing verbal intelligence – are more likely to be in a happy marriage, a Finnish study has found. The effect could be down to more intelligent men being able charm the ladies – or outwit their rivals.

THE BILINGUAL

Parlez-vous français? A study at Montreal's Concordia University has found that speaking a second language may help to protect you from age-related cognitive decline by boosting tissue density in brain areas associated with memory.

GOOD MONTH

BAD MONTH

UNDERGROUND COMMUTERS

Sound levels on some London Underground journeys can reach upwards of 85 decibels, leaving passengers at risk from potential hearing loss and tinnitus, researchers at University College London have found.

RETIREEES

If you are saving like crazy and planning for a leisurely early retirement, you might want to have a rethink. A team at University College London has found that cognitive function and short-term memory take a rapid nosedive after retirement due to the sudden lack of stimulating work.





SPACE

HAS ELON MUSK SPARKED A 21ST-CENTURY SPACE RACE?

On 6 February at 3:45pm at the Kennedy Space Center in Florida, private aerospace company SpaceX launched the Falcon Heavy, the most powerful operational rocket in the world. Around eight minutes later, the rocket's two side boosters touched down on landing pads in perfect sync, while the upper stage sent the payload – a cherry-red Tesla Roadster 'driven' by a spacesuit-wearing mannequin – hurtling into interplanetary orbit.

A few hours after the rocket launch, the company's billionaire CEO Elon Musk told the gathered press of his ambitions for space travel. "I think it's going to open up a sense of possibility," he said. "We want a new space race. Races are exciting."

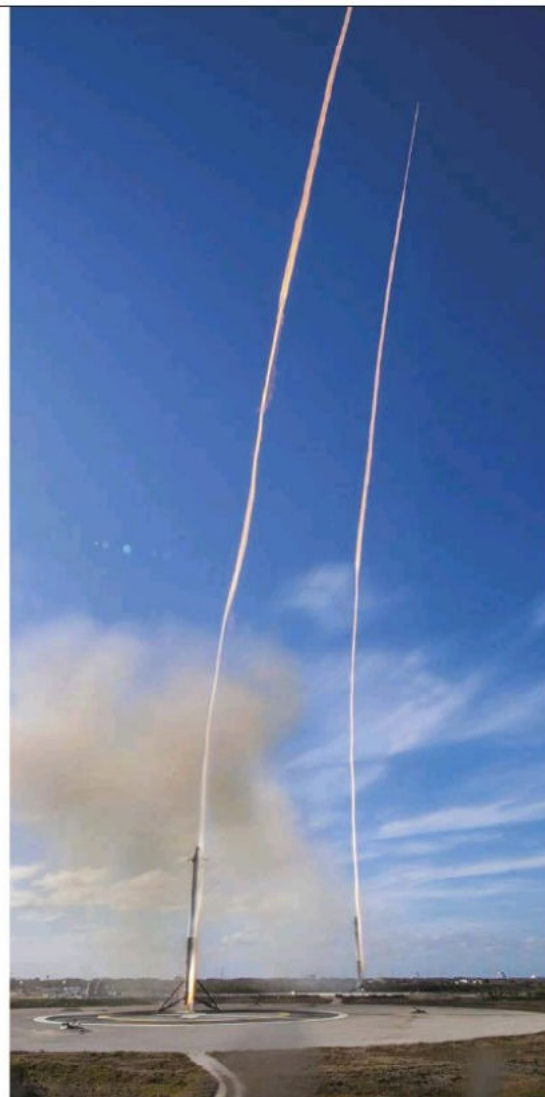
CLOCKWISE FROM ABOVE:
The Falcon Heavy blasts off from the Kennedy Space Center; live views from the Tesla Roadster were streamed back to Earth; the two reusable side boosters returned to Earth shortly after launch; after being launched aboard the Falcon Heavy, the Roadster is now travelling through the Solar System

While there's no doubt that Musk is a man used to getting what he wants, most commentators believe there is still some way to go until we see anything even approaching the scale of the back and forth battle that went on between the Soviet Union and the US in the 1960s.

"I don't think we have a space race yet," says Robert Massey, deputy executive director of the Royal Astronomical Society. "To be honest, Elon Musk doesn't really have any competitors – he's clearly leading the field. Not to dismiss the efforts of others but I certainly think he has changed the paradigm."

In little more than 15 years, SpaceX has gone from being a wide-eyed Silicon Valley start-up to the most talked about name in spaceflight – a

PHOTOS: SPACEX X4



field traditionally dominated by national space agencies such as NASA and their private contractors Boeing and Lockheed. And it's not alone: Blue Origin, owned by Amazon founder Jeff Bezos, beat SpaceX to the punch in landing a reusable rocket for the first time in November, and Richard Branson's Virgin Galactic continues to carry out regular test flights.

With private companies grabbing the headlines, it may seem like government agencies have been overtaken by ambitious billionaire-funded private companies. According to Massey, this isn't the case. "What you have seen in recent years is that the ambitions of NASA have been in more distant destinations, so they are kind of saying they can leave the low Earth orbit stuff to private companies because rocket technology is so mature," he says.

It's also worth noting that government agencies are likely to be some of the private companies' biggest customers and their biggest source of income.

"ELON MUSK
DOESN'T
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— HE'S
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LEADING THE
FIELD"

"SpaceX is already tied to NASA, as it is delivering supplies, and ultimately people, to the Space Station," says Massey. "It's also likely that the first customers of the Falcon Heavy will be national space agencies, probably NASA."

Both SpaceX and Blue Origin are now working on rockets designed to take humans into space — Blue Origin on the New Glenn reusable rocket, and SpaceX on the BFR, a 100m-tall monster that Musk says will take humans to the Moon for the first time since 1972.

"I think it is conceivable that SpaceX will achieve their goal of sending people around the Moon. The difference between going around the Moon, to landing a vehicle, having people walk on the surface, returning to lunar orbit, returning to Earth orbit — that's a lot harder," says Massey. "My hunch is that will be done by a state, possibly the Chinese as they want to do it as a matter of national pride. I could be completely wrong, nobody expected SpaceX to develop in quite this way."

MICHAEL MOSLEY ON... **TURMERIC****"IS TURMERIC JUST A FOOD FAD, OR COULD THIS SPICE REALLY BE BENEFICIAL FOR YOUR HEALTH?"**

Until quite recently, the only place that you'd probably encounter turmeric would be in a chicken tikka masala.

But it has now become incredibly trendy, thanks to claims that it can improve everything from allergies to depression.

When it's fresh, turmeric looks a little bit like ginger root (in fact, they belong to the same family), but when it's ground down you get a distinctive yellowy-orange powder that's very popular in South Asian cuisine. There are at least 200 different compounds in turmeric, but there's one that scientists are particularly interested in. It's called curcumin. Thousands of papers have been published looking at turmeric and curcumin in the lab, and some have had promising results. But the tests have mainly been done in mice, using unrealistically high doses.

Yet there have been some exciting human studies too. There was, for example, one with the delightful title, *Curry Consumption And Cognitive Function In The Elderly*. In this study, the scientists looked at just over 1,000 Asian subjects, between the ages of 60 and 93, and compared their levels of curry consumption with their cognitive performance, as measured by their Mini-Mental State Examination (MMSE) score. The researchers found that those who consumed curry 'occasionally' or 'often' had significantly better cognitive scores than those who 'never' or 'rarely' consumed curry. For the BBC series *Trust Me, I'm A Doctor* we also did a turmeric experiment. We recruited nearly 100 volunteers who rarely ate curry and divided them into three groups. We asked one group to consume a teaspoon of turmeric every day for six weeks, ideally mixed in with their food. Another group swallowed a supplement containing the same amount



of turmeric, and a third group took a placebo pill.

To see what effect the turmeric had, we used a novel test developed at University College London by Prof Martin Widschwendter. His test looks at methylation, which is a process by which changes happen to the DNA of cells. It is a bit like a dimmer switch that can turn the activity of a gene up or down. To see if eating turmeric made any difference to genes, we got him to test our volunteers' blood before and after the experiment. So what did he find?

"We didn't see any changes in the group taking the placebo. The supplement group also didn't also show any difference," he says. "But the group who mixed turmeric powder into their food – there we saw quite substantial changes," he continues. "It was really exciting, to be honest. We found one particular gene which showed the biggest difference. And what's interesting is that we know this particular gene is involved in three specific diseases: depression, asthma and eczema, and cancer... so this is a really striking finding."

But why did we see changes only in those eating turmeric, not in those taking the same amount as a supplement? Dr Kirsten Brandt, a senior lecturer at Newcastle University who helped run the experiment, thinks it may have something to do with the way the turmeric was consumed. "It could be that adding fat or heating it up makes the active ingredients more soluble, which would make it easier for us to absorb

the turmeric," she says.

There is more research that needs to be done, including repeating this experiment to see if these findings can be confirmed. But I'm already experimenting with adding it to tea and my morning omelette. **G**

Dr Michael Mosley is a science writer and broadcaster, who presents *Trust Me, I'm A Doctor* on BBC Two. His latest book is *The Clever Guts Diet* (£8.99, Short Books).

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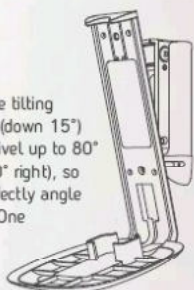
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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

MARCH 2018

EDITED BY RUSSELL DEEKS



The Formula E's greater energy storage capacity means teams will be able to complete an entire race at higher speeds without the need for a mid-race car swap

NEW FORMULA

Formula E is racing into its fifth season this year with a striking new car design.

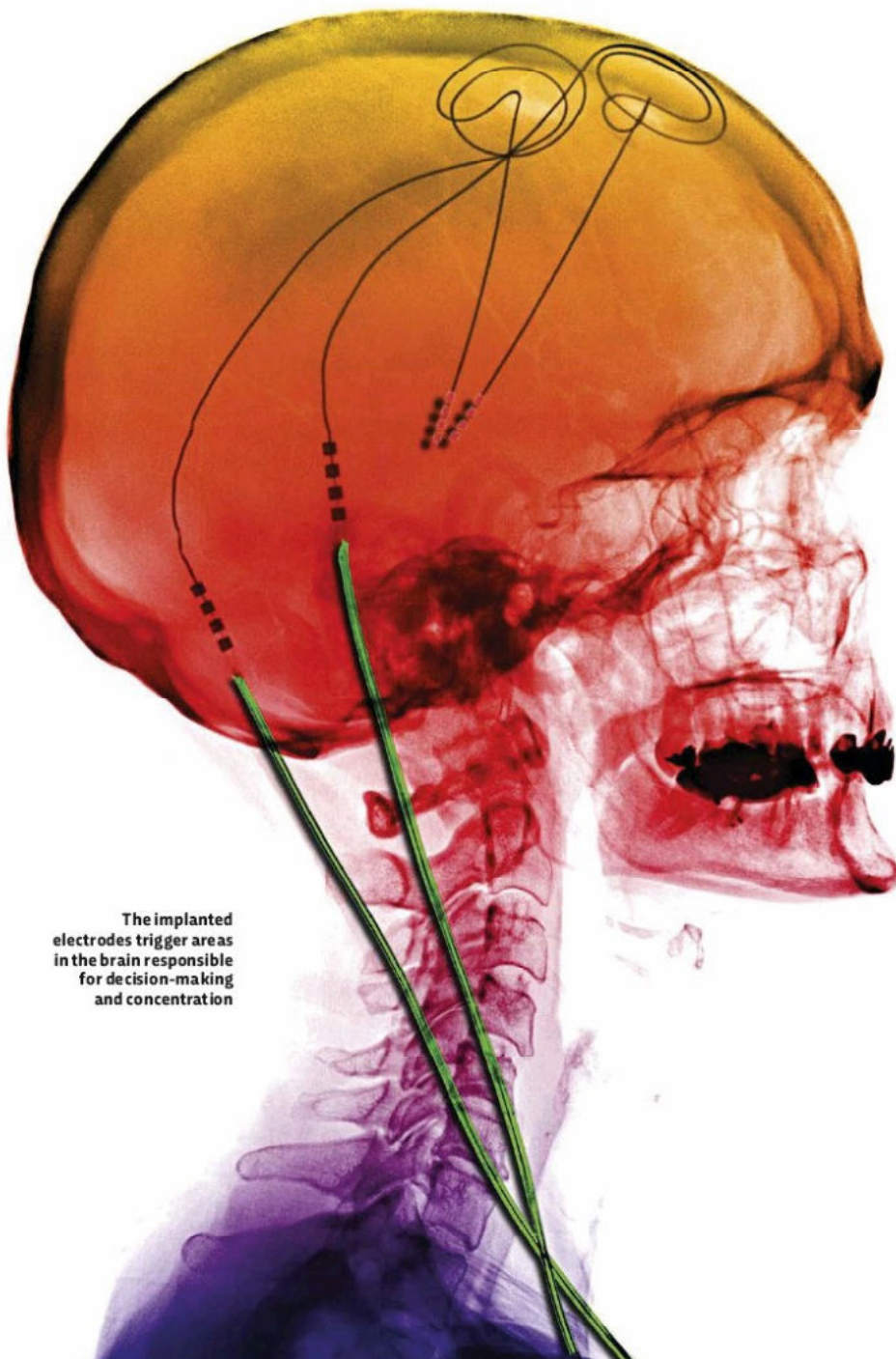
In Formula E, all racing teams use the same chassis and battery. This second-generation car, which will be used for the next three seasons, has been built – like the first – by French company Spark Racing Technology. Its battery, supplied by McLaren, has double the capacity of the previous one, which means drivers will no longer need to switch to a second vehicle halfway through each race.

Measuring 1.8m wide by 5m long, the car weighs in at 885kg – some 87kg heavier than its predecessor – yet now boasts a top speed of around 300km/h (186mph), compared to the original vehicle's 225km/h (140mph).

Meanwhile, more obvious changes to the car's design include aggressively styled front wings and a large diffuser at the rear, as well as a ring of lights around the protective 'halo' that surrounds the cockpit and guards against head injuries.

HEALTH

NEW TREATMENT RECHARGES DECISION-MAKING IN ALZHEIMER'S



The implanted electrodes trigger areas in the brain responsible for decision-making and concentration

More effective treatments for Alzheimer's disease could be just around the corner, thanks to a technique called deep-brain stimulation (DBS), research just published in the *Journal of Alzheimer's Disease* suggests.

Deep-brain stimulation involves implanting electrodes inside a patient's brain that stimulate key areas of the frontal lobe by means of a tiny electric current, provided by a 'battery pack' implanted in the patient's chest. The technique has already proved successful in treating neurological conditions such as depression and Parkinson's disease, while in 2016, studies found that it could help to stimulate brain cell growth and slow memory loss.

Building on this research, a team at the Ohio State University led by Dr Douglas Scharre, gave three Alzheimer's patients DBS implants then tracked their cognitive function over three years. All three patients experienced less cognitive decline than would normally be expected, and in some cases there were actually signs of a reversal: one patient was able to cook a meal for the first time in several years.

"We have many memory aids, tools and pharmaceutical treatments to help Alzheimer's patients with memory, but we don't have anything to help with improving their judgments, making good decisions, or increasing their ability to [focus] on the task at hand. These skills are necessary in performing daily tasks," says Scharre.

A follow-up study involving a much larger group of patients is now being prepared.



The innovative Mofrel printing system can replicate a vast number of textures

COMPUTING

CASIO LAUNCHES TEXTURE PRINTER

Imagine being able to put a piece of plain white card into your office printer, and have it emerge at the other end as a thin slab of wood, a sheet of rubber, a piece of fabric – or even a strip of alligator skin. In actual fact, this is no longer a fantasy, because Casio has just unveiled a printer that can do just that, and more.

The Mofrel system is best thought of as a cross between traditional ink-on-paper printing and 3D printing. It creates complex objects by building up thin layers of molten plastic or metal. An image or 'map' of the desired textured material is printed onto thin card containing layers of carbon molecules,

which is then subjected to infrared light. This causes the carbon molecules to expand, with the card becoming thicker in the darker areas of the image, creating the desired texture. The sheet can then be printed over using standard inkjet inks to give it the required colour or pattern.

The only catch is the price: a Mofrel printer starts at approx £33,200, while the special card it uses costs £7 per A4 sheet. So for now, it's really intended as a fast-prototyping device for manufacturers and product designers. However, as 3D printing has already made the leap from industry to consumer, textural printing looks likely to follow.

TECHNOLOGY

FIRST FOR FILMING EARTH

Guildford-based satellite imaging company Earth-i has just launched a satellite that will, for the first time, beam back full-colour, high-res video of Earth from space.

High-quality still satellite images have been available for years, as have short video clips, but the new satellite – which was launched via an Indian rocket on 11 January – will be the first to supply high-resolution footage on a continual basis. It was, however, just a test-run. If successful, it will be like a live Google Earth.

Earth-i's long-term goal is to build a constellation of 15 satellites called Vivid-i that encircle the planet and, if the test goes well, it plans to launch five satellites a year from 2019 onwards.



One of Earth-i's fleet of high-resolution imaging satellites, which will eventually encircle the Earth

1



2



3



4



5



6



WANTED

1 HOME HELP

Apple's recent entry into the speaker-plus-voice-assistant market is this 172mm tall, Siri-enabled unit that packs seven tweeters and one four-inch bass/midrange speaker. It's compatible with HomeKit, but multi-room audio won't arrive till later.

Apple HomePod
£319, apple.com

2 SUPER SHARP SHOOTER

Here's a camera aimed at serious – 'happy to spend over £43K on a camera' – photographers. It's medium-format and can shoot still pictures at up to 400 megapixels, plus capture 4K video. The hefty price tag doesn't include lenses.

Hasselblad H6D-400c
£43,500, hasselblad.com

3 BETTER PUTTER

Want to improve your performance on the green? TaylorMade's new putter has a built-in Blast Motion golf sensor that will track backstroke velocity, impact stroke speed and face rotation, then relay the info to an app so you can monitor your game.

TaylorMade Spider Interactive Putter
\$400 (£290 approx), taylormadegolf.eu

4 FOR PLAYPEN PRODIGES

It might look like a toy... and it is. But unlike other nursery noise-makers, the Blipblox aims to introduce kids to the joys of sculpting their own synthesised waveforms, while MIDI and audio I/O mean it can slot neatly into a grown-up studio too.

Playtime Engineering Blipblox
Price TBC, blipblox.com

5 LIGHT 'EM UP

Razer's new gaming speakers include two three-inch woven glass fibre drivers and feature its Chroma lighting system. Using the Synapse 3 app, you can sync them with your Philips Hue smart lights for a more immersive gaming experience.

Razer Nommo Chroma
£170, razer.com

6 BAD TO THE BONE

This sleek, LED-sporting bike helmet from Coros has bone-conduction speakers, so you can listen to music without headphones blocking out traffic noise. You'll get eight hours' playback from a single charge, plus there's an internal crash sensor.

Coros Omni
\$200 (£145 approx), coros.com



7

NINTENDO EMBRACES BOARD SPORTS

Introducing the Switch-enhancing Labo kits

As if the Nintendo Switch's shape-shifting abilities weren't innovative enough, Nintendo has just pushed the gaming envelope that little bit further with Labo, a set of build-it-yourself accessories made of cardboard.

Two Labo kits are available: the £60 Variety Kit and the £70 Robot Kit. Each one contains sheets of cardboard parts that you pop out and fold together to build game-specific controllers, or 'Toy-Cons', following instructions provided by videos and animations on the accompanying disc. Once that's done, you slot either of the Joy-Con controllers or the Switch tablet itself into your creation, and you're ready to play.

The Variety Kit contains a set of motorcycle handlebars, a fishing rod, a racing car, a 13-key piano and a house; the Robot Kit is sold separately because its multiple parts are used together to build a robot-like bodysuit. The accompanying games are fairly simple – the real fun here lies in building the Toy-Cons themselves. But by the time you get bored of those, the forthcoming Toy-Con Garage software – which will let you preprogram and reassign your new controllers to your heart's content – should also be available.



FIRST LOOK - NISSAN LEAF

LEADING THE CHARGE

Nissan's trailblazing Leaf gets a radical overhaul, but can this car convince the masses to go electric?



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On Tenerife's southern shores, a few miles down the road from the island's all-you-can-eat resorts, sits ITER, a research institute dedicated to sustainable living. Here, nestled in the island's volcanic rock and surrounded by towering wind turbines and glistening solar panels, Nissan decided to launch its most important car to date – the new, all-electric Leaf.

The location illustrates Nissan's ambitions for this car. The ITER site not only generates its own electricity for research, but actually funds itself, in part, by selling the excess electricity generated by its photovoltaic plants and wind farms. Nissan hopes that the new Leaf will be able to do the same: it won't just be a set of wheels, but a ticket to a more sustainable lifestyle that might save you a few quid along the way. Could it possibly live up to the hype?

ELECTRIC DREAMS

The first number you need to know is 258 miles (415km). That's the reported range of the Leaf when you're pootling around a city. That figure drops to 168 miles (270km) when the measurement combines 'urban' and 'motorway'

driving. It's enough range to drive you from London to Bristol without any anxiety, or as far as Exeter, if you're brave. Regardless, the Leaf's range is now approaching Tesla distances, which means that in our experience it's more than enough to manage trips. The

next key number is 40 minutes, which is how long Nissan says its car will take to charge from 10 per cent to 80 per cent battery on the newer 50kW quick chargers (which Zap-Map, a list of the UK's charging units, tells me are in good supply, apart from in Wales). And finally the next most important figure is 26 per cent. This is the amount by which the torque has increased. In other words, the Leaf has got more powerful, managing 0-60mph in a remarkable eight seconds.

The numbers tell an impressive story but there's a lot of improvement inside the Leaf too. The standout innovation is the e-Pedal, which lets you drive the car with just the one pedal. It works simply: push the 'gas' pedal – I suppose that term seems a bit archaic now – to go, and lift up to brake. Lift off abruptly and



CLOCKWISE FROM LEFT: The Leaf's first European airing was in Tenerife, a volcanic island that's also a pioneer in renewable energy; the charging socket has been moved from the side to the front of the car; the interior is smart, if a little traditional for an electric car; the infotainment system has had a minor upgrade and now supports Apple Carplay and Android Auto



the car comes to a quick but measured stop; ease off the pedal gently and the car slows gradually. Any deceleration charges the battery back up and turns on the brake lights. In a sense there's nothing new here. The previous Leaf and almost all other electric cars offer levels of regenerative braking. Once you pick your resistance level, the braking kicks in when you lift off, slinging you and your passengers into your seat belts on all but the lightest setting. But after a short learning period the e-Pedal becomes second nature, and after just half an hour, I'm a convert. It's a simple bit of design that means you'll drive more economically without even realising it. Don't worry, the actual brakes are there for an emergency!

Of course, economy and sustainability were on the hymn sheet throughout the

"IT'S A SIMPLE BIT OF DESIGN THAT MEANS YOU'LL DRIVE MORE ECONOMICALLY WITHOUT EVEN REALISING IT"

launch. If you can afford it, the Leaf lets you buy into an ecosystem of products that could potentially help you run your car for next to nothing. The idea is that you could pair your new all-electric car with some solar panels and a wall

battery. You then charge your batteries either via sunlight, or from the grid, and sell extra energy in the car that you don't need back to the grid at times of peak demand. It's a brilliant idea, as long as you have your own driveway or garage. It's worth mentioning that new Leaf customers will get a 7kW wall charger for free too.

SAFETY FIRST

The Leaf isn't just being pitched as a smart ecosystem, it comes as standard with a host of intelligent safety systems too. Lane departure warning honks will blast out if you veer too far over the white lines. And if you keep going, the car will intervene by slowing down the inside wheels to pull you back on track. There's also Cross Traffic Alert that'll warn you if you're about to get



● side-swiped when pulling out at a junction. For an extra £400 you can get the Leaf equipped with ProPilot. This is a Level 2 autonomous system, which means the steering and speed can be controlled by the car, using a combination of radar and camera sensors, but the driver is ultimately considered in control of the vehicle. None of the kit is ground-breaking, but it's great to see all this tech on an electric car at this price.

KERB APPEAL

The original Leaf suffered from a bit of a bulbous carriage. It had the kind of looks that owners had to apologise for. Mercifully, Nissan has smoothed out the Leaf's bumps and sharpened its edges. At a glance, there's little to signify that you've ditched the fossil fuel habit beside the missing exhaust, which has been replaced by

a racy rear diffuser. The interior has also improved dramatically. The dowdy, worthy-looking innards have been upgraded, but the interior looks a little too 'normal' for our tastes. This might appeal to most motorists, but it left us wishing for something a little more futuristic.

Nissan's infotainment system has had a bit of a facelift and comes installed with Apple CarPlay and Android Auto, which is probably the most fluent way to connect your car and smartphone.

The Leaf's cabin cocoons you from a decent amount of wind and tyre noise, and since there's no engine to compete, the seven-speaker Bose sound system (which comes with the pricier Tekna model) outperforms what you'd find in more expensive cars.

VERDICT

Many credit Tesla with sparking the electric car switchover, but in reality, the Roadster, the Model S and the cars that followed were only ever an aspiration for most motorists. The Nissan Leaf, in contrast, makes the strongest case yet for the average car owner to stop filling up and start plugging in. It goes further, charges faster and is bursting with smart technology. It's even pretty fun to drive, too! The Leaf is a car you really ought to try. 📱

9/10

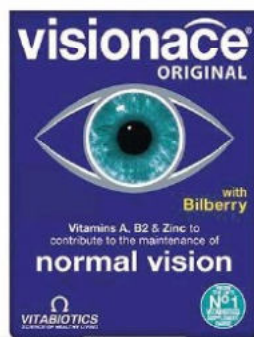
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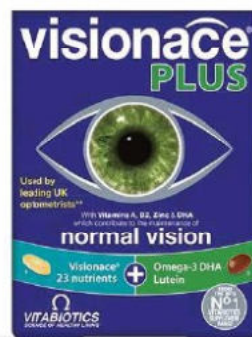
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Longmeadow garden plan in this issue

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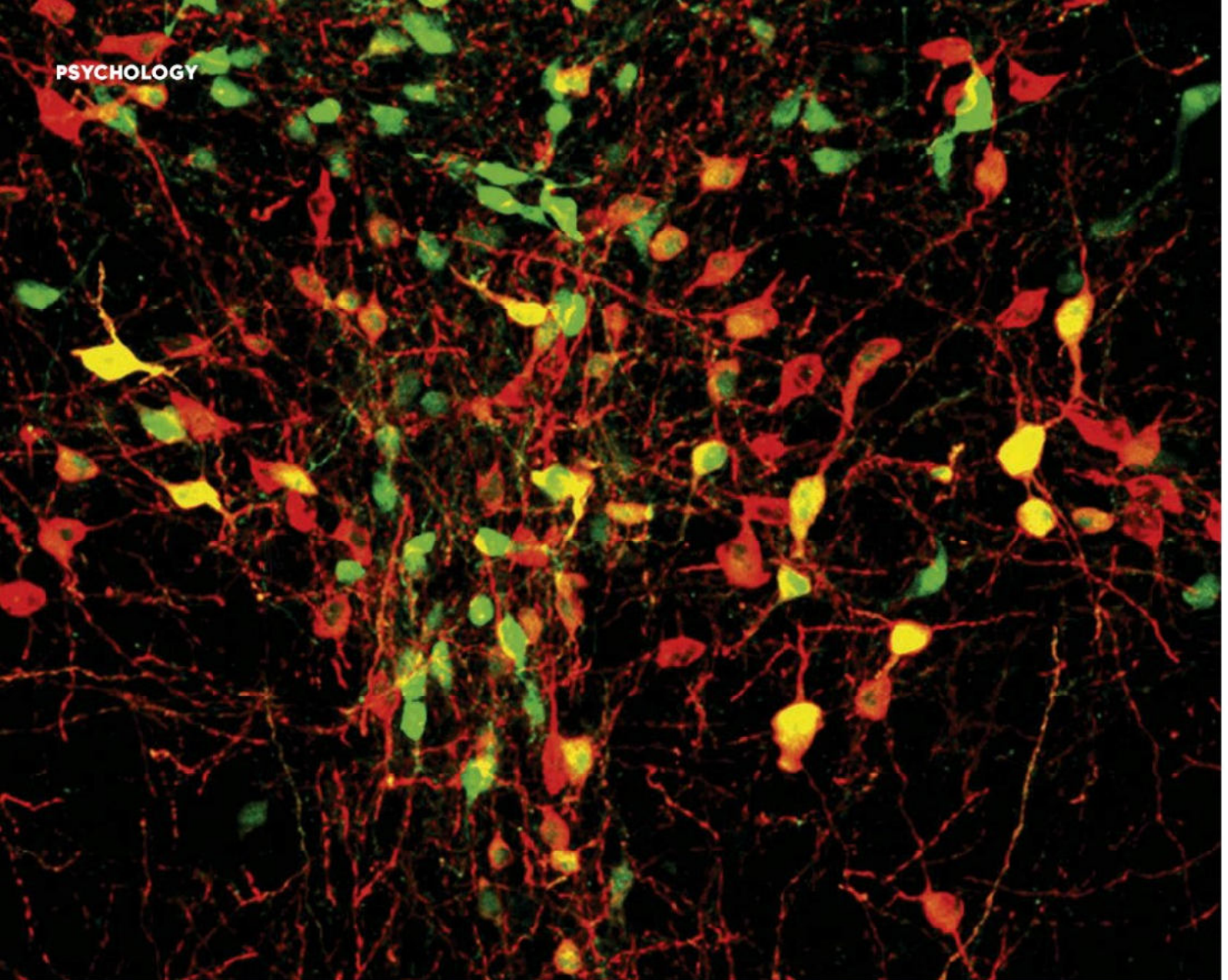
YOU ARE NOT ALONE

Loneliness is worse for you than smoking, and more harmful than obesity. As the number of lonely people in the UK swells, we investigate why feeling alone literally hurts, and how we can stop it from making us ill

WORDS: MOYA SARNER



Visit bit.ly/bbc_lonely to take part in the BBC's Loneliness Experiment and help create what could be the world's largest ever survey of its kind on loneliness.



Today, society is becoming ever more divided. But if there is one thing that's bringing everyone together, it's loneliness. Scientists, doctors, charity workers and politicians from across the political spectrum all agree that loneliness is a big problem. A report published in December 2017 by the Jo Cox Commission revealed the staggering extent of loneliness in the UK. Almost one-quarter of parents surveyed by the charity Action for Children said they were "always or often lonely", more than one-third of people aged 75 and over told Independent Age that their "feelings of loneliness are out of their control", and over the course of a year more than 4,000 children called Childline because they felt unbearably lonely – some as young as six years old. One recent study found that nine million adults in the UK suffer from chronic loneliness: if all the lonely people moved to one city, it would be bigger than London.

This isn't just sad – it's dangerous. Research shows that experiencing chronic loneliness is as bad for our health as smoking 15 cigarettes a day, and worse than obesity. It is associated with an increased risk of developing coronary heart disease and stroke, and increases your likelihood of early mortality by 26 per cent. But how does this happen? How can an emotional experience be so bad for our physical health? Prof Steve Cole, a medicine and genomics researcher at the University of California, Los Angeles, says part of the answer may

ABOVE: In one study, MIT researchers have found that feelings of loneliness can be traced to the brain's dorsal raphe nucleus (pictured)

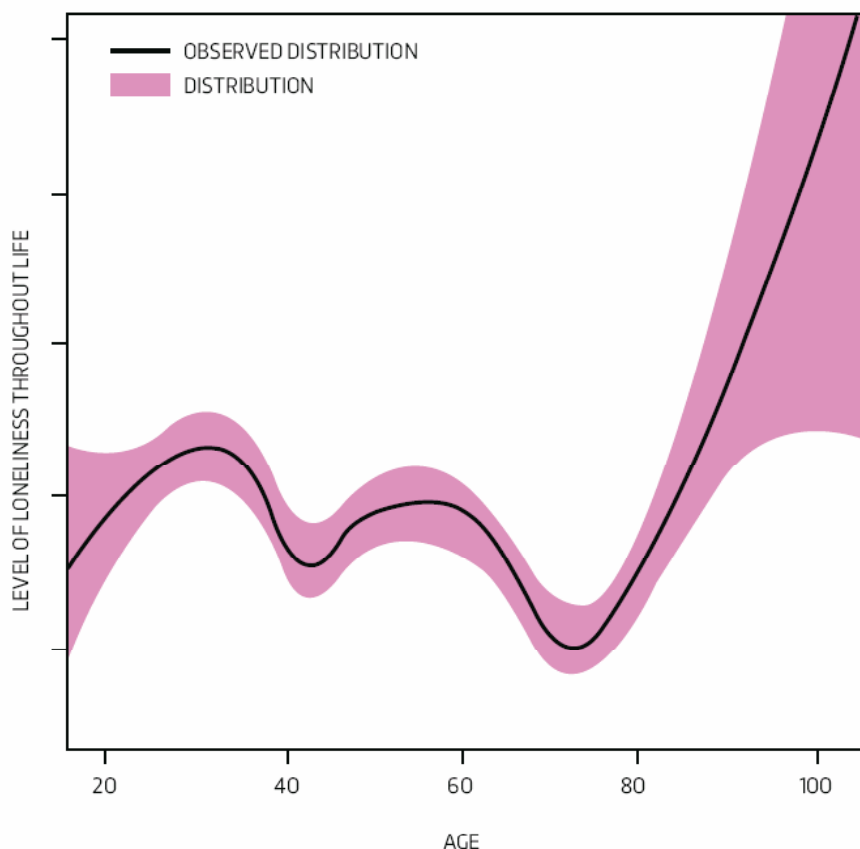
RIGHT: In January this year, Tracey Crouch was appointed the minister for loneliness, in response to rising levels of loneliness and social isolation



LONELINESS THROUGHOUT LIFE

"We know from population studies that there are two big peaks of loneliness over the lifespan: one in young adulthood and one in older age," says psychiatrist Dr Farhana Mann. While causes of loneliness in later life may seem obvious, provoked by the loss of social networks that can come with retirement, bereavements and mobility problems, loneliness in adolescence happens for different reasons. "Chronic loneliness exists in young people, particularly those who are ostracised. The social world of adolescents is perilous because frankly, that is the most status-conscious period of our individual trajectories. That is when young people can feel least valued by their peers. There is an incredible level of competition that comes from the primed reproductive system, and people who don't fare well feel incredibly bereft," says Prof Steve Cole, a researcher at the University of California, Los Angeles.

For Dr Juliet Wakefield, senior lecturer in psychology at Nottingham Trent University, the question is less about age and more about life stage. "The risk of loneliness is especially high during times of transition in our lives: when we become a student, a parent, a retiree, a widow. At these points there is the risk of us losing our connection with groups we belonged to before the transition," she says.



ABOVE: Contrary to stereotypes, research has found that loneliness is not restricted to old age. Research published in *Developmental Psychology* surveyed 16,132 people and found that while the causes of loneliness in the elderly is well understood, less is known about what causes it in youngsters

"Research shows that experiencing chronic loneliness is as bad for our health as smoking 15 cigarettes a day, and worse than obesity"

lie in the impact loneliness has on our immune system. His research shows that people experiencing chronic loneliness undergo a shift in the molecular programming of their immune cells: instead of being primed to fight viruses, their bodies prepare to fight bacterial infection – the kind that follows a wound or injury. This is the temporary state the body switches into with the fight-or-flight response; the crucial difference is that lonely people get stuck there. Long term, this leads to higher levels of inflammation, which in turn contributes to cancer, heart attacks, Alzheimer's and depression. "Loneliness, oddly enough, is one of the most threatening states we confront," Cole explains.

PRICKLY PEOPLE

But this response to loneliness can also affect our brains, leading us to behave in ways that leave us even more isolated. When these inflammatory signals reach the brain, they change certain aspects of how it functions, including social motivation, making us more defensive, guarded and prickly – not exactly the state of mind best suited to a party mood. Scientists have seen this happen in brain scans: in a study that investigated the hyper-vigilance of lonely people, participants had their brain activity monitored while they were shown images picturing a social threat, such as bullying, and a non-social threat, such as a shark. The researchers found that lonely people responded faster to social threats than to other kinds of dangers, ●

beating the participants who weren't lonely. This could help explain why some people become entrenched in their loneliness: when we start to feel isolated, it can make social interaction feel like a more alarming experience, as we can become more attuned to potential threats in the facial expressions and body language of those around us. That can make us feel more suspicious and less inclined to connect with others, which can leave us feeling even more isolated. "That lonely immune biology feeds back to the brain in ways that might exacerbate and potentially perpetuate loneliness, leading to a vicious cycle of loneliness begetting biology, which in turn begets loneliness," says Cole.

It turns out we are even lonely when we're asleep. A recent study into 2,000 young adults by postdoctoral researcher Dr Timothy Matthews at King's College London found that lonelier people reported poorer sleep than non-lonely peers, and were 24 per cent more likely to feel tired and have difficulty concentrating during the day – an association that remained after controlling for mental health problems. The link was almost 70 per cent stronger among those who

RIGHT: Channel 4 documentary, *Old People's Home For 4 Year Olds*, saw a group of young children and pensioners brought together every day for six weeks to enjoy various activities. The experiment aimed to see whether the wellbeing and mental health of the elderly people would improve because of interaction with the kids. It was such a success that they were all reunited for a Christmas carol concert and snowball fight



“Just as hunger is your body’s way of telling you that you need to eat, loneliness is like an alarm bell signalling that you need to reconnect with people”

had been exposed to severe forms of violence in their teenage years. “When you feel like you’re on your own, the world seems like a more threatening place, which could make it harder to sleep restfully,” Matthews says. “This perception of threat in the environment seems to be even stronger for people who’ve been exposed to an objective threat during their lives, such as being a victim of violence.” This also helps us understand why lonely people’s immune systems could be primed to fight bacterial infection from a wound, rather than viral infection; they are anticipating being attacked by a predator, with no tribe to defend them.

These findings fit with the evolutionary theory of loneliness. “The theory goes that humans are social creatures and our ancestors would have needed to stick together in groups in order to succeed, so having an instinctive aversion to being isolated would have served an adaptive purpose. Just as hunger is your body’s way of telling you that you need to eat, loneliness is like an alarm bell signalling that you need to reconnect with people,” explains Matthews. Loneliness is a kind of social hunger – it’s a message telling us we need to feed our social selves.

But when it comes to working out how to do that, we still have a long way to go. Much of that is to do with attitudes, says Dr Farhana



How to build village life in the big city

The obvious first step is to start an activity or group that brings people together, but there is one trap that people often fall into, says Dr Farhana Mann, a psychiatrist at University College London. "If you truly want to build a sense of community, you may need to go outside your comfort zone. We tend to associate with people who are similar to us because it's familiar – one of the major challenges is bringing in people who are more marginalised," she explains. So if you're looking to set up a local group to create a sense of connection in the area where you live, you also need to think: how can I extend this to people with mental health problems, to people from less represented minorities, to people who are less well off, to children and older people? "That might mean talking to someone who works in a mental health service, contacting existing community groups, and trying to reach those who are most vulnerable," she says.

Mann, a psychiatrist at University College London: "People will go to their GP and tell them about whatever lesion they have, but saying they're lonely is just too embarrassing. We need to give people a sense that it is absolutely legitimate to talk openly to their GP or other health professionals about this, because it's a genuine health issue."

GROUP CHAT

Mann hopes that in the coming months and years, we'll see more social prescribing, where isolated people are referred to a local organisation with expertise in what is going on in the area, so patients can nurture their social relationships. Alongside this, she wants to see more community development where local residents decide what activities they want to engage in, using the skills that members of the communities already have.

"There's no point rushing in to set up groups without talking to the people who make up that community," says Mann. For example, you could end up bringing Beethoven concerts to an area where everybody wants a gardening and a cooking group. And groups that already exist for other purposes – such as diabetes management groups, for example – can be better used to combat social isolation. "Although they are not for loneliness on the label, they may work just as

RIGHT:
Feelings of
loneliness,
anxiety and
sadness can
be alleviated
with animal
therapy
sessions – who
wouldn't feel
happier after
cuddling this
cute lamb?






well, because the effect of being in a group of people with a shared experience could have a positive impact," she adds.

There is a lot that we still don't understand about loneliness – particularly when it comes to mental health. "There is certainly evidence for a strong link between depression and loneliness; being lonely makes you more likely to get depressed, and if you are depressed you are more likely to experience loneliness," says Mann. But it is not the same with all mental health problems, and that is where more research is needed. "There is far less evidence about the experience of loneliness for people with other diagnoses like schizophrenia, bipolar disorders, or anxiety disorders. The subtlety of the nature of your mental health problem may influence how you experience isolation, and in turn what you find helpful," she says.

A counterintuitive finding to come out of recent research is that increasing social networks of lonely people is not always the appropriate intervention. Loneliness and social isolation are not the same;

many individuals feel lonely even when surrounded by people. "Some people who feel lonely have cognitive biases that make them interpret their relationships as not being satisfying or truly meaningful, so those friends are not really true friends somehow," says Prof Louise Arsénault, a developmental psychologist at King's College London. "I think that people should not focus on how many friends they have, but should focus on one or two relationships only, to make those satisfying and meaningful, so they can really discover the meaning of friendship." 

Moya Sarnier is a freelance writer and editor.

Why does loneliness trap some people, while others can come out the other side?

SOCIAL NETWORK

"Having a social network around you can be helpful in practising social skills. Some people have been so isolated they don't remember how to interact, or have lost confidence in their ability to do so," says psychiatrist Dr Farhana Mann.

MENTAL HEALTH

"Depression tends to make people want to withdraw from others, which makes it very difficult to join social groups and develop a sense of belonging," explains psychology lecturer Dr Juliet Wakefield.

INSIGHT

People can have more success beating loneliness if they seek help. "The fact that someone tells me they're lonely allows us to have a conversation that may help; I don't know exactly what will work, but we can talk about it and address it," says Mann.

DEPRIVATION

"Poverty can make loneliness very difficult to escape from, as it means that the person has fewer resources at their disposal, and this can make it difficult to access social groups in the first place," explains Wakefield.

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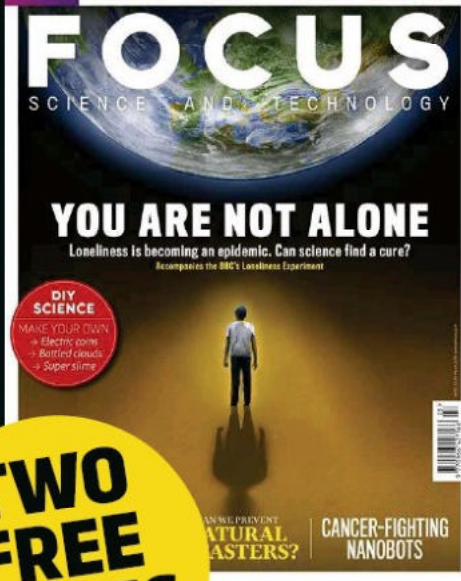
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PREPARE FOR GROLAR BEARS...



WE ALL KNOW ABOUT RISING TEMPERATURES AND MELTING ICE CAPS, BUT WHOEVER HEARD OF THE GROLAR BEAR? HERE ARE SOME OF THE LESSER-KNOWN IMPACTS OF CLIMATE CHANGE

WORDS: HAYLEY BENNETT

GROLAR BEARS

Some say 'grolar', others prefer 'pizzly'. Whichever it is, this grizzly-polar bear cross, or hybrid, is the result of two habitats colliding under the influence of climate change. While melting sea ice is forcing the remaining polar bears ashore, the previously frigid Arctic is becoming increasingly bearable to grizzlies venturing north.

Encounters with grolar bears – including one shot by a hunter in northern Canada in 2016 – seem to be

on the rise, suggesting the two species may be mating more often. The hybrid bears are fertile, so there's been talk of a new species emerging. However, Dr Andrew Derocher, a bear biologist from the University of Alberta, Canada, doubts this will happen. "Predicting evolution is a fool's game," he admits. "However, my best guess is that we won't see a new species. Grizzly bears could easily absorb a bit of polar bear DNA and keep on going." In fact, he adds, grizzlies in

some of the islands off the north coast of Venezuela have carried DNA from polar bears since polar bears were further south tens of thousands of years ago. A 2017 study suggests that hybrids prefer to mate with grizzlies over polar bears, which should protect the polar genome – though polar bears themselves may die out. Other climate-driven crosses include a number of different seal hybrids, as well as beluga-narwhal whales spotted in western Greenland.

MORE MURDERS

Crime and aggressive behaviour are often noted to increase during heatwaves. This could be a physical reaction to changes in, for example, heart rate and hormone levels, or it could be a psychological reaction caused by discomfort and stress; scientists are still trying to work it out. In 2014, however, a study in the *Journal Of Environmental Economics And Management* went one step further, predicting that climate change in the US will cause 22,000 more murders, 180,000 more rapes and 1.2 million more aggravated assaults between 2010 and 2099. Researchers have even tied wars and the collapse of societies such as the Mayans to climatic changes.



WORSE-TASTING COFFEE (AND WINE, AND BEER!)

Changes in weather patterns will leave less land suitable for coffee-farming. Half of Ethiopia's coffee-growing regions could be lost, and those areas most suited to coffee production will be the hardest hit, according to one 2017 study. The changing climate will affect other drinks, too. Some craft beers need cool overnight temperatures to draw in wild yeasts from the air, while in vineyards, temperature determines when the grape harvest starts. So far, hotter summers have made for earlier harvests and better-tasting wines, but experts think we'll soon reach a point where the heat, coupled with increasing rainfall, will reduce quality.



WORSE ALLERGIES

There's bad news for those of us who suffer from sneezing or wheezing. Hotter summers and higher levels of carbon dioxide encourage plants to produce more pollen for a longer stretch of the year. Climate change is also interfering with the spread of pollution, which can trigger asthma symptoms. These changes could lead to more frequent and intense episodes of hayfever and asthma, the World Allergy Organization warned in 2015.



MORE LIGHTNING

Lightning strikes will increase by about 12 per cent for every 1°C rise in temperature, according to a study in *Science*. In theory, a warmer atmosphere is capable of holding on to more moisture, which creates conditions more conducive to lightning. Additional strikes could pose a serious risk as lightning also sparks off wildfires.



MESSED-UP MARINE SOUNDS

In water, sound travels faster at warmer temperatures. If the ocean is warmer or colder than we expect, it throws out our underwater communications systems. This could lead to problems finding an aeroplane's black box, or make it hard to avoid whales and dolphins. It could also interfere with animals' own communication systems, crucial in mating and migration. Researchers have already discovered an area of the Arctic Ocean where sound travels four times further than it did a decade ago.



TINY ANIMALS

Animals shrink during periods of warming. Over generations, that is, not before your eyes. It's thought to be because increasing their surface-area-to-volume ratio makes them more efficient at getting rid of heat, though whether this happens through natural selection or other factors such as lack of food isn't known.

Last year, Abigail Carroll of the University of New Hampshire published a study on prehistoric 'dwarfing' based on fossils from mammals similar to horses, rabbits, lemurs and weasels. During two hot periods around 54 million years ago, these animals tended to be tinier than at other times in the fossil record, but not quite as tiny, the study found, as during an even hotter period around two million years earlier. She says the same thing is likely to happen under current global warming. "There are already mammals that seem to be responding in this way," she says. "The red squirrel in California is showing it, and the red deer." She adds that domesticated animals like horses and dogs will be far slower to respond as they're under our influence more than that of the climate. Meanwhile, in the event that climate change causes a mass extinction, some scientists are predicting (somewhat dubiously) that we will see scavengers such as gigantic rats evolve in order to fill any empty niches.

Humans have selectively bred horses to be different shapes and sizes, but the fossil record suggests that changing climate may have reduced the size of earlier horse-like species

MIGRATING NORTH POLE

Climate change is shaking our world to its core, almost literally. Changes to the way water is distributed across the planet – including the melting of the Greenland and Antarctic ice sheets, which contain 99 per cent of the world's freshwater ice – are shifting the Earth's axis. Although the axis hasn't always stayed put, recent changes caused by humans are altering its trajectory. Since 2000, the North Pole has been heading in the direction of continental Europe at a rate of about 16 to 18 centimetres a year. If this continues, geographic north, which is calculated from the long-term average position of the Earth's rotational axis, may eventually have to be updated. (Though a compass will always point towards magnetic north.) The shift itself may not be too concerning, but it is yet another reminder of our influence on the planet.



BUMPIER PLANE RIDES

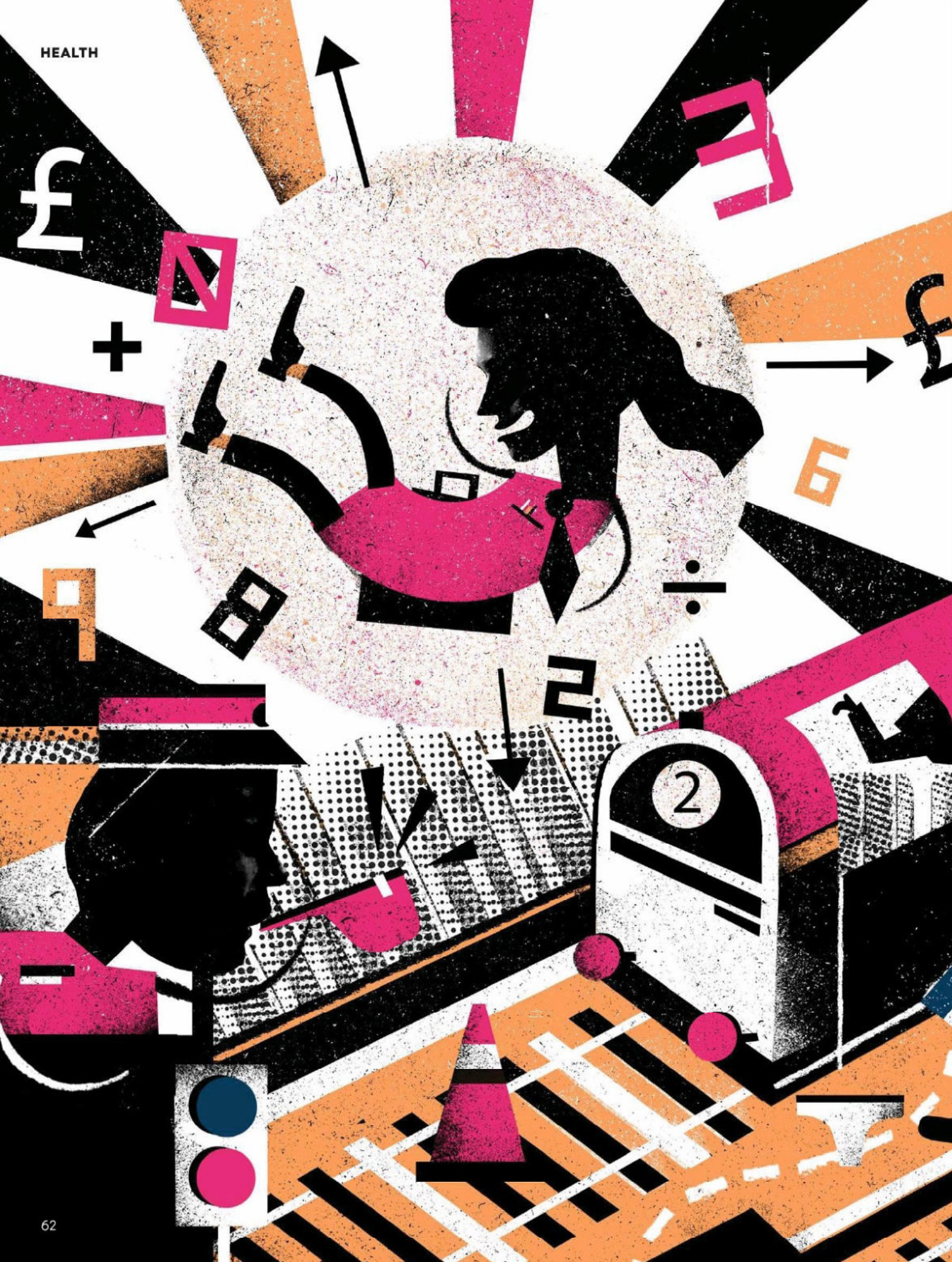
Jet-setters, beware. Travelling by plane could be riskier in the future due to an invisible type of turbulence. Clear-air turbulence is increasing because of the way the jet stream – a fast-flowing air current high up in the atmosphere – is speeding up as a result of climate change, explains Prof Paul Williams, who studies atmospheric sciences at the University of Reading. “We have evidence that the jet stream over the north Atlantic, at flight levels, is blowing at a few miles an hour faster than it was a few decades ago,” he says. The faster the jet stream blows, the more likely the air is to become unstable, and when it becomes unstable, it results in turbulence. Clear-air turbulence is more dangerous than turbulence created by clouds because pilots can’t spot it ahead of the plane, so the seatbelt sign is usually off. Williams is one of the authors of a recent study that predicts a doubling of clear-air turbulence over North America, Europe and the North Pacific by the end of this century. Laser detection systems offer a possible solution, but they’re currently heavy and expensive. “It would cost an airline more money to retrofit their fleet with this technology than they would save from the avoided injuries,” says Williams.



DISRUPTED SEX LIVES

Rising temperatures could have a profound influence on the sex lives of reptiles, making it harder for them to find a mate. In green sea turtles, for example, hatchlings from eggs incubated above 29°C are female, while those from eggs incubated at cooler temperatures are male. Populations are usually female-dominated, but in 2016, a study in the Caribbean found that only 16 per cent of green sea turtles are male, and predicted that by 2030, the percentage will fall to just 2 per cent due to climate change. **F**





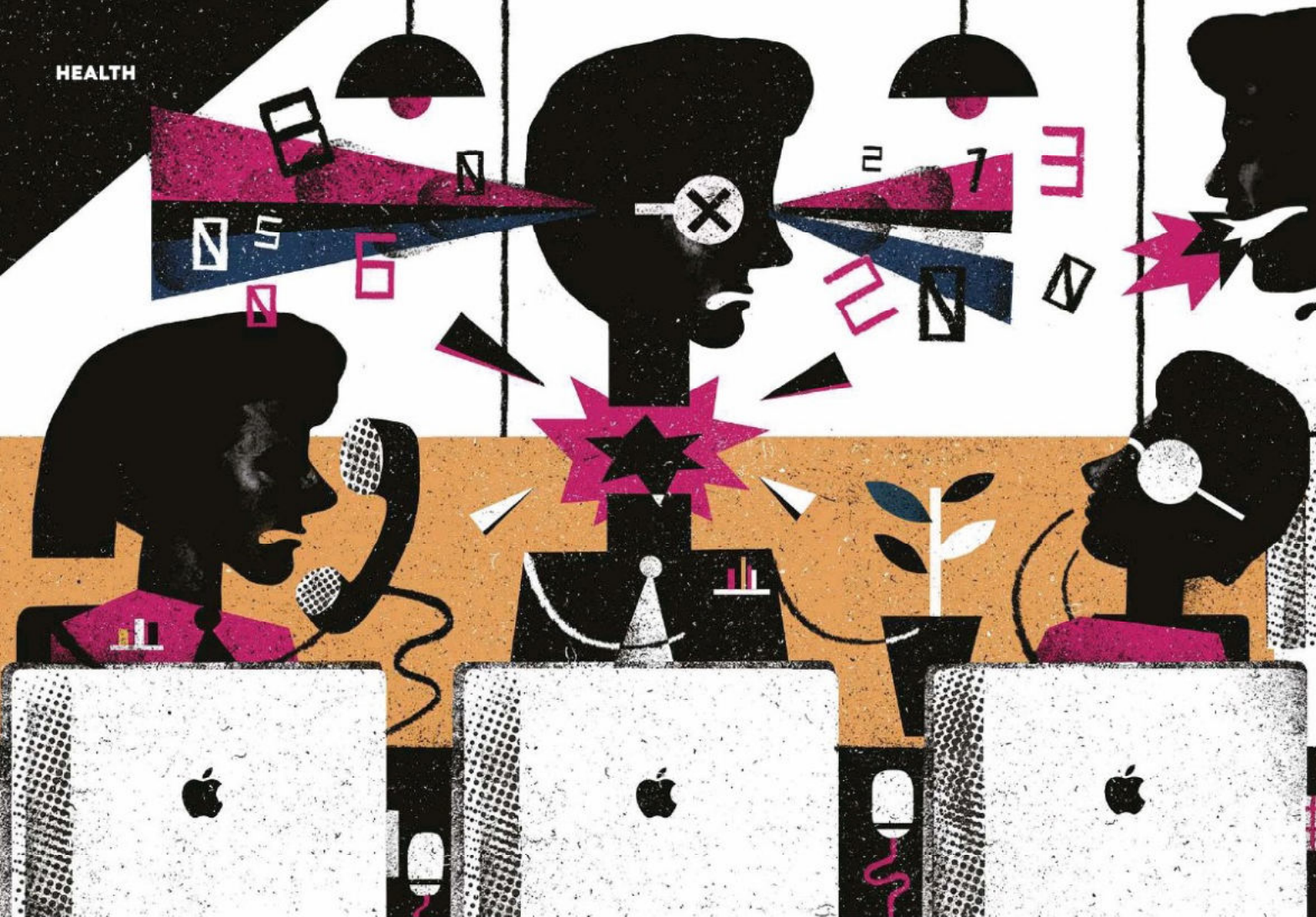
STRESS-PROOF YOUR LIFE

Got an endless to-do list?
Heart racing? Dreading the 9-5?
If this feels familiar, then it's
time to take back control

WORDS: SIMON CROMPTON ILLUSTRATIONS: JAMES MINCHALL

Every generation thinks it's the most stressed. In the 19th Century, doctors warned that workload, education and too much information from newspapers was producing an anxiety-inducing cacophony of voices that was affecting the national wellbeing. Rest cures, nerve tonics, relaxation techniques and a kind of yoga were all the rage as cures for so-called 'nervous exhaustion'. Today, little has changed. In fact, the World Health Organization has labelled stress as "the health epidemic of the 21st Century".





● A long-running population study of women in Gothenburg, Sweden, found that in 1969, 36 per cent of women felt stressed, yet by 2005 the number had doubled to 75 per cent. Similarly, an analysis of self-reported data by Carnegie Mellon University in the US found that stress levels have increased by as much as 30 per cent over three decades.

The possible reasons behind soaring stress levels are constantly being proposed: too many things to engage us from too many directions; increasing expectations of our productivity; 24-hour availability; the social pressures that information technology brings.

But recent research indicates a common thread: lack of control. The 21st Century has seen a significant rise in situations where people have little autonomy but are under pressure to bring results quickly. In work, this type of stress has been found to reduce life expectancy. A 2016 study from Indiana University found that those in low control, high-stress jobs have a 15 per cent increase in likelihood of death, compared to those with low job demands.

And the problem is that the more we move in stressful environments, the more

stressed we feel. A new scientific study has found that students who are taught by burned-out teachers display higher levels of stress hormones like cortisol than their fellow students who are taught by calm tutors. It seems that 21st-Century stress has all the qualities of an old-fashioned 19th-Century contagion.

So, if we are currently living in an age of anxiety, then what's the effect on us? Doctors define stress as your body's response to mental or emotional pressure. That response centres on two triangular adrenal glands sitting on top of each kidney. When we feel threatened, these glands release the stress hormones adrenalin and cortisol, which switch off the body's long-term repair projects in favour of short-term

“Research over the past 20 years is revealing increasing evidence of the dangers that long-term stress poses to our health”



measures to help you to deal with a crisis. They are the 'worry about the consequences later' hormones, increasing our heart rate and blood sugar levels to give us energy, but dampening down our digestion, our ability to rest and our immune response. These effects are helpful in a short-term crisis. It helped our ancient ancestors to run fast if they were being chased by a wild animal. Yet in the modern era, where we aren't being chased by sabre-toothed cats, short bursts of stress can still be useful. A new study from the University of Vienna indicates that humans are more likely to help others when under stress. The researchers scanned people's brains while they were simultaneously stressed by time tasks and asked to respond to photos involving other people's welfare and pain. The team found that the neural empathy network reacted more strongly when under stress. Short-term stress might also make us temporarily more optimistic, as experiments have shown that we pay more attention to positive information and discount the negative when we're under pressure.

STRUGGLING WITH STRESS

But the problem is that modern stressors – from noisy neighbours to exam pressures – tend to be continuous rather than short-term. And research over the past 20 years is revealing increasing evidence of the dangers this long-term stress poses to our health.

Prof Stafford Lightman, an expert in stress-related disease at Bristol University, explains that if stress hormones like cortisol are raised continuously over say 24 hours, the responses it provokes can start to cause damage. "Cortisol is an anticipatory hormone, which is normally at its highest when you wake up, but you need a holiday from it so that the body can recuperate," he says.

Chronic stress has been linked to increased blood pressure, heart attacks, reduced learning, depression, ●

ARE YOU NATURALLY PRONE TO STRESS?

Everyone gets stressed, but some people seem more susceptible to pressures getting on top of them. It's not just a simple matter of genetics – although scientists have found genes that do seem to affect our ability to cope when the going gets tough. What's becoming increasingly clear is that stress in childhood can affect the way genes express themselves, and these epigenetic changes seem to be linked with conditions such as depression. Studies in animals are showing that stress in early life makes it much more likely that stress will prompt mood problems in adulthood. Childhood stress seems to trigger biochemical changes that alter the way genes express themselves. Once they've happened, these 'epigenetic' changes can be passed down through the generations. So the stresses your parents or grandparents experienced in childhood may account for why you're easily wiped out by high-pressure situations.



● teeth grinding, obesity, hair loss, acne, lowered fertility, susceptibility to infections and some types of cancer.

"The mechanism by which chronic stress causes damage varies from tissue to tissue," explains Lightman. In the brain, for example, long-term cortisol exposure reduces the links between cells in the hippocampus, the part of the brain which mediates memory. In other parts of the body it may be exposure to other substances released during the stress response – adrenaline, inflammatory cytokines, glucocorticoid steroids – that do the damage. Continual stress seems to affect the body's ability to regulate inflammation, particularly in the arteries, and this causes tissue damage and immune system disruption.

This year, medics demonstrated for the first time that people with higher activity in the amygdala, which is the instinctive part of the brain that signals the release of stress hormones, are more likely to experience heart attack, angina, heart failure, stroke and arterial disease. Their research, published in *The Lancet*, monitored the health and brain activity of 293 people over four years.

AND BREATHE...

It's perhaps no surprise that as awareness of the risks of stress are growing, many individuals are increasingly obsessed with attempting to stress-proof their lives. Meditation training is a booming industry, recently valued at more than \$1bn (approx £750m) in the US. The *Headspace* mindfulness app alone is worth £25m. Many schools and employers are now routinely teaching

"Meditation training is a booming industry, recently valued at more than £750m in the US. The *Headspace* mindfulness app alone is worth £25m"



A VACCINE FOR STRESS?

Scientists have long observed that physical and mental problems caused by stress have a strong association with immune system changes. This has given rise to a new wave of research, looking at whether modifying the immune system through vaccines might make us more resilient to stress. Neuroscientists at Columbia University, US, have transferred immune cells from chronically stressed mice to unstressed mice, and found that the unstressed mice became more resilient to stress, showing fewer depressive symptoms. Separately, neuroscientists from the University of Colorado have modulated the immune system of mice by injecting them with species of bacteria known to decrease



anxiety. When these mice were placed in a cage with aggressive animals, they were less intimidated than unimmunised mice, and later displayed none of the stress-related gut problems that the unimmunised mice had. Could this mean an anti-stress vaccine is a possibility? Christopher Lowry, lead researcher at Colorado, has announced he is pushing forward with human trials. Ultimately, he believes the bacteria – given by pill, inhalation or injection – could help people buffer the physical and behavioural side effects of stress. Soldiers at risk of PTSD are the most obvious candidates for the bacterial stress vaccine, says Lowry. But who knows what next? A pre-exam vaccine for pressurised teenagers?



their students and staff about time management, prioritisation techniques, mindfulness and yoga.

So do all of these stress management techniques actually do any good? Prof Marc Jones, a stress and emotions expert at Staffordshire University, says that there are certain techniques both to help you deal positively with stress in the moment, and to help you relax between demanding situations so that stress does not become chronic. Both have a role. "Different things work for different people," he says. "What we've found is that people who feel challenged rather than threatened by a demanding situation such as a test or a public talk respond with increased cardiac output and blood vessel dilation. These people perform substantially better than those who have a threat response, where there is little or no change in cardiac output and blood vessels constrict. The challenge response is: 'It's difficult, but I'll do it'. The threat response is: 'I'm not sure about this, I want to avoid it'. What we've found is that physiological response consistently predicts how well people do in these demanding situations."

It is possible, he says, for all of us to learn mental techniques to help us feel 'challenged' rather than 'threatened'. "It's about focusing on what you can achieve rather than what might go wrong," he says.

So what might be the best ways of stress-proofing your life? On the following pages are 10 scientific approaches to dealing with stressful situations, and tips to give your brain time out of stress mode. ●

STRESS MYTHS: TRUE OR FALSE?

STRESS TURNS YOUR HAIR GREY

This is probably true. After all, we've seen country leaders go grey within weeks of taking office. The subject hasn't been studied much, but a paper published in *Nature* in 2013 did find that hormones produced in response to stress can cause the melanocyte stem cells that determine hair colour to leave our hair follicles.



STRESS WILL GIVE YOU STOMACH ULCERS

Nope. Common stomach ulcers are caused by an infection by *Helicobacter pylori* bacteria, not by stress. However, stress and other lifestyle factors like drinking alcohol and eating spicy food may make existing ulcers worse.



STRESS GIVES YOU WRINKLES

Probably true. At the end of our chromosomes is a protective cap of DNA called a telomere. Telomeres shorten as we age, and studies have shown that stress can prematurely shorten telomeres, speeding up the ageing process. One study showed that long-term anxiety caused by phobias was linked with shortened telomere length, suggesting that stress might accelerate ageing.



A POST-WORK DRINK HELPS YOU DE-STRESS

Wrong again. There's evidence that people who report high levels of stress tend to drink more. In the short-term, alcohol can help you relax and take your mind off troubles. But studies indicate that regularly using booze to de-stress has the opposite effect – your body becomes immune to alcohol's effects and stress hormone levels rise.





HOW TO BEAT STRESS

FORGET TAKING A CHILL PILL, THESE 10 SCIENTIFICALLY PROVEN TECHNIQUES WILL HELP YOU PROTECT YOUR BODY AND YOUR BRAIN FROM THE DAILY GRIND

1. TAKE CONTROL

"Perceiving that we have control over what might happen is a very important way for us to be able to deal with demanding situations," says Prof Marc Jones, a stress and emotions expert. "People often go into job interviews thinking they don't know what they're going to be asked, they don't know what they're going to say. Instead, think: what can I control here? Focus on very simple things you *can* control like how you walk into the room, how confident you appear. It's about

building up our own resources to deal with stress differently." Research shows that this mental 'reframing' can genuinely help people's performance under stress. Jones's team at Staffordshire University found that the way a climbing task was verbally described to participants significantly changed how they approached the challenge: they did much better if it was made explicit that they had control of the situation.

2. CALCULATE THE ODDS

There are other techniques we can use to help improve our mindset when we get stressed. For example, Frank Ghinassi, associate professor of psychiatry at the University of Pittsburgh, recommends everyday tips such as calculating probabilities of things actually going wrong instead of 'catastrophising'. If a worst-case scenario has a 1 in 10 chance of happening, then how much of your attention does it deserve?

3. SNACK ON FRUIT AND NUTS

Snacking on some fruit and nuts on stressy days may reduce stress and its damaging effects on the body. Recent tests have indicated that blueberries help counter the effects of PTSD in animals. And walnuts seem to prepare the body for stress, according to American researchers. They found that adding walnuts or walnut oil to people's diets reduced blood pressure responses to stress in the laboratory.

4. WALK IN THE WOODS

People who live in more natural environments tend to have lower levels of cortisol and fewer signs of chronic stress. Even if you live in the city, just getting out in the countryside can help. Japanese research on Shinrin-yoku – meaning 'forest bathing' – has found that woodland environments lower cortisol, pulse rate and blood pressure. "It's a pretty consistent finding that engaging with nature is a positive way to recover from stress," says Jones.

5. GET YOURSELF A DOG

Dogs are great motivators for going outside and getting some exercise. But their company can also be a stress buster – especially for children. Children aged between 7 and 12 have been found to get much less stressed about arithmetic and public speaking tasks when they have their dog with them. Having a parent present did not have the same effect. Another study shows that owning a pet reduces blood pressure.

6. HAVE A CUP OF TEA

It's the classic British response to a crisis: "Would you like a cup of tea?". And there is some evidence suggesting it provides more than a psychological boost. Research from University College London found that people who drink black tea become relaxed more quickly after a stressful task, and their cortisol levels return to normal at a faster rate. There is still uncertainty about which tea ingredient accounts for this. But separate Portuguese research has indicated that the weak concentration of caffeine found in tea reduces anxiety symptoms in mice!

7. PLAY VIDEO GAMES

There is evidence that playing video games can help reduce stress, which flies in the face of those who blame all our ills on screens. Cognitive psychologists at the University of Central Florida have shown that frazzled workers benefit more from playing a simple video game during a short work break than sitting in silence or taking part in guided relaxation. This is backed by studies indicating that military veterans who regularly play computer games as a means of escape tended to have served longer and cope better with physical and psychological stressors.



8. JUMP ON YOUR BIKE

It's boring but true: exercise reduces stress. This year, Canadian researchers reported that those who cycle to work display far lower levels of stress within the first 45 minutes of work than those who commute by car or public transport. Other studies have indicated that how stressed you feel in the early morning affects stress levels throughout the day. According to the Mayo Clinic in the US, exercise relieves stress by pumping up endorphin levels and forcing the brain to focus on movement alone.



9. GET HITCHED

Studies have found that stress gets worse if you're lonely. Engaging with other people, particularly loved ones, buffers stress and helps you break out of a personal perspective. For years, research has indicated that married people are healthier than single, divorced or widowed people, and now there's evidence that this is directly related to lower stress levels. Research at Carnegie Mellon University, which was published in 2017, showed that married couples have consistently lower levels of the stress hormone cortisol. But any form of engagement with other people may help: research shows that social isolation is strongly associated with increased blood pressure as well as higher cortisol levels.

10. EAT PREBIOTICS

Prebiotics are compounds that promote the growth of good bacteria in the gut. Foods high in prebiotics include Jerusalem artichokes, chicory, garlic, leeks, onions, asparagus, bananas and whole wheat. New animal research has indicated that eating prebiotics prolongs REM sleep, which is believed to be essential for recovery from stress and stress disorders. This links with other research indicating that keeping your diet healthy and your gut happy helps to buffer stress. A recent study of 60,000 Australians, reported in the *British Medical Journal Open*, found that people who ate five to seven portions of fruit and veg daily had a 14 per cent lower risk of stress than those who ate zero to four. 🍌

Simon Crompton is a science and health writer. He tweets from @Simoncrompton2

A STORY OF ICE AND FIRE

Around the planet, temperature plays a hidden part in the symphony of life. Helen Czerski's new programme reveals just how surprising its effects can be

WORDS: DR HELEN CZERSKI



Dr Helen Czerski is a physicist, oceanographer and broadcaster. Her latest BBC series is *From Ice To Fire: The Incredible Science Of Temperature*. Catch up on iPlayer. bit.ly/ice_fire



BLACK OR WHITE?

On a hot day, we tend to think that white clothes will reflect sunlight and therefore keep us cool. Yet while black absorbs more heat, it also radiates it away more quickly. A famous paper in 1980 noted that the Bedouin wear black robes in astonishingly hot desert conditions, but found that the advantages and disadvantages pretty much cancelled each other out. It turns out that other factors matter much more than clothing colour: for example, loose garments are helpful for heat loss because the air that flows between you and the clothes will cool you down, and a breeze will help too. So wear whatever colour you like!

The Bedouin provide proof that you can wear whatever colour you like in scorching conditions

INVERSE FREEZING

We all know that freezing is the process of cooling down a liquid until it solidifies. But scientists have also discovered a process called 'inverse freezing', where it happens backwards. A solution of two chemicals (alpha-cyclodextrin and 4-methylpyridine) in water starts off as a transparent liquid at room temperature and then becomes a milky white solid once it's heated. When cooled, it returns to a liquid. It's thought that at lower temperatures, the two chemicals cluster together, making the solution liquid. When the temperature rises, the bonds joining them to each other break, and then the whole mixture can crystallise to form a solid.



Most liquids, like water, become solid when they cool down. But some chemicals seemingly defy the laws of physics

THERMAL BULLSEYE

Bees are experts at distinguishing different types of flower, and are capable of using colour, pattern and smell to help them collect nectar efficiently. But now it seems that temperature is also in their sensory toolbox, and they can distinguish 2°C temperature differences on a flower's surface. Many flowers have distinctive patterns of temperature across their petals because of differences in solar heating and variations in the heat produced by the flower itself. A recent study used tiny hidden heaters to make patterns in flower 'targets' and showed that bumblebees used those temperature patterns to identify the best flowers to visit.



Many flowers have differing temperatures across their petals, which help bees to home in on their sweet, nectar-filled target

GREENHOUSE GAS

We're used to hearing about human-generated carbon dioxide contributing to the greenhouse effect, but the major greenhouse gas in Earth's atmosphere is actually water. A planet's temperature is determined by the balance between the incoming solar energy and the heat that's radiated away. If our atmosphere didn't contain any water, the energy flowing in and out would be balanced at an average temperature of -18°C. Water vapour in the atmosphere diverts some of the outgoing heat (via the greenhouse effect), and shifts the balance point to a far more pleasant 14°C. Human-generated greenhouse gases are now nudging the average temperature even higher.



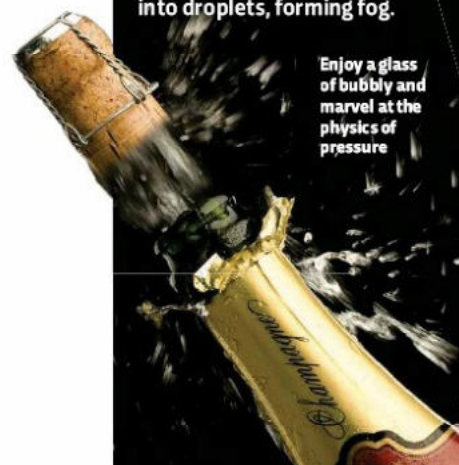
Water helps our planet stay at a balmy average of 14°C

PHOTOS: GETTY X4, FLPA/INGO ARNDT

CHILLY BUBBLES

If you wanted to chill something down to -60°C, then you'd probably think about buying an expensive freezer, yet this is exactly what happens every time you hear a champagne cork pop. When a compressed gas expands into the atmosphere, it cools (that's why the spray from an aerosol always feels cold). The greater the ratio of the initial and final pressures, the greater the cooling. The gas in the neck of a chilled bottle of champagne has a pressure of around four atmospheres, which is roughly the same pressure experienced by a scuba diver at a depth of 30m. As the cork flies away and the gas expands outwards, the temperature in the bottle neck briefly plummets to -60°C. The cold makes water condense into droplets, forming fog.

Enjoy a glass of bubbly and marvel at the physics of pressure



SWEAT PATCH

In a hot environment like the African savanna, staying cool is essential for survival. And giraffes have several clever adaptations to prevent themselves from overheating. Their large nostrils allow them to lose huge amounts of heat via airflow, while the dark patches on their skin act as 'thermal windows' from which heat can escape. Beneath each of those dark patches is an especially dense network of capillaries, and the skin itself contains enlarged sweat glands. On a hot day, blood can be redirected to the patches to be cooled efficiently by sweating, before returning to the heart.

Giraffes' patches don't just look pretty, they also help them stay cool





The Arctic ground squirrel is the only mammal whose core temperature plunges below freezing when it hibernates

“An Arctic ground squirrel’s core can drop to -2.9°C , with their brain and neck barely above 0°C ”

ON ICE

Every hibernating mammal will reduce their core body temperature to save energy, but only one is known to survive a core temperature below freezing: the Arctic ground squirrel. Implanted temperature probes have shown that their core can drop to -2.9°C , with their brain and neck barely above 0°C . That’s astonishing by itself, but more recent studies have found that during hibernation, the squirrels lose huge numbers of the connections between their brain cells and then regrow them each time they wake up. It’s thought that this is the most efficient way for their brains to survive the low temperatures.

SHINY SPACESHIPS

The futuristic spacecraft drawn by excited artists in the 1950s may not have arrived as imagined, but those artists did get one thing right: spacecraft are shiny, and always will be. This is all to do with temperature. Take the International Space Station: full sunlight can raise its surface temperature to 121°C , while spending an hour in Earth’s shade can drop the same surface to -157°C . The only way to keep the occupants safe is to reflect away as much sunlight as possible, using a shiny, silvery mesh made from aluminised mylar that blocks all solar radiation.



Full sunlight can raise the ISS’s temperature to dangerous levels, but a reflective coating keeps things comfortable

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- James Heard, 17, Participant

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CAN WE STOP



NATURAL



DISASTERS?

In 2017, there were 10,000 deaths due to natural disasters. But could science help us prevent these catastrophes before they happen?

WORDS: Prof Bill McGuire

HOW TO STOP A

VOLCANO



Tungurahua, also known as 'Throat of Fire', is an active volcano located in Ecuador

Yellowstone is no ordinary volcano. Three times in the last couple of million years, this so-called supervolcano, located in the western US, has blown itself apart in some of the biggest explosions ever known. The last, which happened around 630,000 years ago, pumped out enough ash to cover most of the country, and left behind a giant crater – the Yellowstone Caldera – more than 70km (44 miles) across. The huge volumes of sulphur gas blasted into the atmosphere by the eruption would have blotted out the Sun, causing global temperatures to plunge and spawning a volcanic winter that lasted for several years.

But Yellowstone is still restless. Earthquakes are common, the ground repeatedly swells and sinks, and the area is peppered with boiling springs, mud pots and geysers. A gigantic body of magma still lurks beneath the volcano, so another massive eruption could happen some time in the future. There are concerns that the resulting volcanic winter might destroy our civilisation, but not if we can take action to try and stop it first. And that's just what Brian Wilcox and a team of researchers at NASA's Jet Propulsion Laboratory have proposed. The idea is to drill into Yellowstone

to 'let off steam'. I've often been asked about this particular solution, and my answer has always been that such a venture would be akin to sticking a drawing pin in an elephant's bottom. In other words, the effect would be pretty much zero. But NASA has given the idea a little more thought and come up with something that might actually work. This is geoengineering on a huge scale.

In NASA's plan, the drawing pin becomes an 8km-deep borehole drilled into Yellowstone's hydrothermal system. This is the vast body of hot groundwater that surrounds the magma chamber and feeds the springs and geysers. The hydrothermal system absorbs more than two-thirds of the heat generated by the magma. In NASA's scheme, huge quantities of cold water would be pumped down the borehole, helping the hydrothermal system suck out even more heat; the idea being that the magma would cool, get stickier, and start to congeal. This, in turn, would mean that it was too viscous to rise towards the surface and feed an eruption.

If Yellowstone were ready to blow, it would need to be cooled by 35 per cent to stop the eruption in its tracks, and this wouldn't come cheap. NASA estimates the cost would be \$3.5bn (£2.4bn). It would take hundreds, or even

HOW IT WORKS

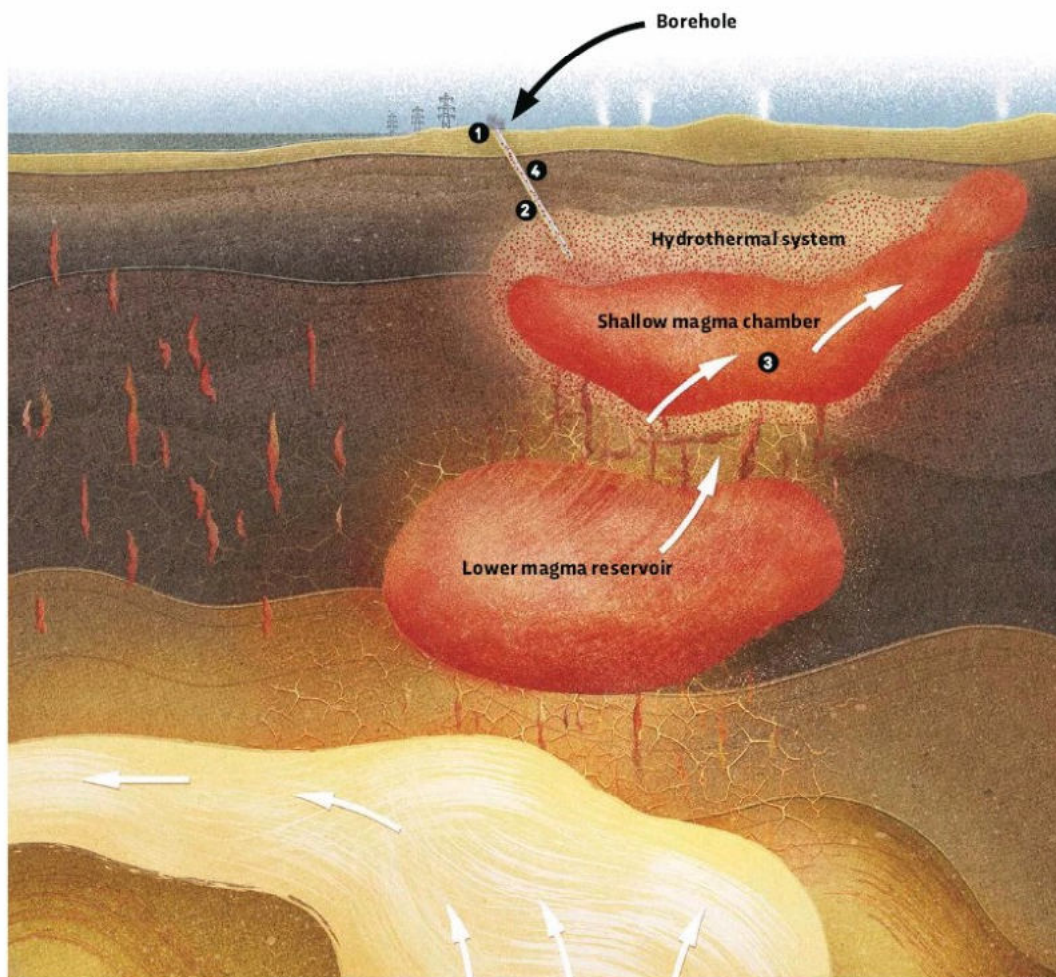
NASA wants to pump water into the Yellowstone volcano to make the magma too sticky to rise.

1 An 8km-deep borehole is drilled into the hydrothermal system. This vast body of hot groundwater surrounds the shallow magma chamber and absorbs more than two-thirds of the heat generated there.

2 Huge quantities of water are pumped down the borehole, cooling the hydrothermal fluids so that they can suck out even more of the magma's heat.

3 The magma cools and starts to congeal, making it more difficult for it to reach the surface and feed an eruption.

4 Superheated water returned to the surface via the borehole could be used to drive turbines and generate electricity.



thousands, of years to accomplish, which is a long time to keep the politicians who hold the purse strings on board. Wilcox acknowledges that this would not be easy, and cautions against doing anything without a detailed study of the pros and cons. "I think it would be unlikely and even foolish to attempt this at any scale, unless a thorough modelling effort had been conducted which shows that the possibility of triggering an eruption was low, almost zero," he says.

But there's good news. Superheated water, returned to the surface via the borehole, could be used to drive turbines and generate energy for the region, which could cover much of the cost. "If it appears possible that economically competitive geothermal power could be produced as part of the 'defanging' of a supervolcano, [this] could close the economic equation sufficiently that people might attempt it," Wilcox observes, perhaps a little optimistically.

There are dangers, of course, and there's the possibility that drilling into a volcano that's primed and ready to go might trigger the blast it's trying to prevent. But with the catastrophic consequences for humans of a future super-eruption, it may turn out to be a risk we have to take.



Springs and geysers at Yellowstone, like the Grand Prismatic Spring pictured here, hint at the volcanic activity below ground

HOW TO STOP A



Tacloban was flattened after Typhoon Haiyan roared through the city in November 2013

Last year will go down in history as the year of the hurricane. In 2017, three storms in the Gulf of Mexico and the Caribbean – Harvey, Irma and Maria – together took more than 300 lives and caused damage totalling \$450bn (£319bn), making it the costliest Atlantic hurricane season ever. As climate change bites ever harder, the most powerful hurricanes are forecast to become more frequent, so years like this may become the norm in decades to come. This has focused minds on ways of stopping hurricanes in their tracks, or even preventing them from forming at all.

One idea – known as the Salter Sink – has been patented by British marine engineer Prof Stephen Salter and billionaire philanthropist Bill Gates. The plan is to float thousands of tyre-like rings in the tropical Atlantic, connected to giant tubes that suck warm surface waters down into deeper water, to be replaced by cold water from below. Hurricanes need sea-surface temperatures of at least 26.5°C to form. If Salter and Gates's gizmo was able to bring surface temperatures down below this, then hurricane formation would be impossible.

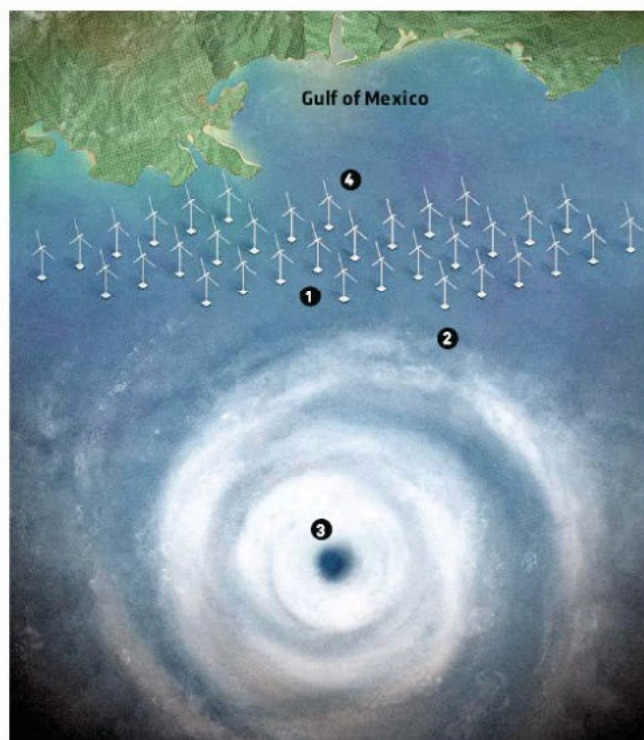
A modified version, patented by Gates and others, has the surface waters being cooled via tubes connected to a line of barges strung out in front of an oncoming storm. Yet a further scheme, put forward by the University of Manchester's Dr John Latham and colleagues, visualises a fleet of unmanned ships roaming the tropical Atlantic. These would spray tiny droplets of seawater into the atmosphere, which would make the clouds brighter so they reflect more of the Sun's heat back into space. This would cool the sea surface beneath and hinder hurricane formation.

Esoteric geoengineering plans that involve messing about with ocean temperatures or cloud formation may, however, hold nasty surprises for global weather patterns. A less risky way forward, then, might be to make use of a technology that is already being developed for a different purpose. At least, that's what engineer Prof Mark Jacobson of California's Stanford University and his co-workers think. If sited appropriately, they say, offshore wind farms could protect coastlines from approaching hurricanes. Jacobson and his team used a computer model to simulate three of the most devastating hurricanes in recent years: Sandy, which

HOW IT WORKS

Simulations suggest that wind farms could slow the speed of hurricanes.

- 1 A giant wind farm, made up of tens of thousands of turbines, is constructed across one of the paths favoured by hurricanes in the tropical Atlantic or Gulf of Mexico.
- 2 As the hurricane approaches the wind farm, the spinning turbine blades hinder and slow down the rotating winds in the outer parts of the storm. This reduces the height of the sea waves beneath the outer parts of the storm, which slows the movement of air towards the centre of the hurricane.
- 3 This results in a rise in atmospheric pressure at the centre of the hurricane, reducing the pressure differential across the storm, slowing wind speeds throughout and dissipating the hurricane faster.
- 4 As a bonus, the wind turbines generate enormous amounts of low-carbon energy.



battered New York in 2012, plus Isaac (2012) and Katrina (2005). Then they ran the simulations with giant, offshore windfarms strung across the paths of the storms, and the effect was by no means small. They found that a huge wind turbine array off the coast of New Orleans could have reduced the peak wind speed of Hurricane Katrina by an astonishing 145km/h (90mph) or so, and the accompanying storm surge, which caused massive flooding, by close to 80 per cent. Offshore wind turbines could have tempered the impact of Sandy too: the computer model projected a fall in wind speed of up to 140km/h (87mph), along with a storm surge two-thirds smaller.

Offshore wind farms sound like a tempting way of killing two birds with one stone, but there may be an issue with the huge numbers of turbines required: 78,000 would be needed to curb the impact of a Katrina-sized storm, for example. The highest concentration of offshore wind farms today can be found in the North Sea, and consists of fewer than 1,500 individual turbines. Still, it's good to know that a green technology could be used to tackle the hurricane threat, and that it's there if we want to use it.

ILLUSTRATION: DANIEL BRIGHT

HOW HARD COULD IT BE?

Other ideas to stop natural disasters have had mixed results

PROJECT STORMFURY



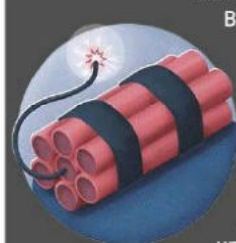
Between 1962 and 1983, US scientists tried to weaken hurricanes by seeding them from aircraft using silver iodide. The chemical was supposed to freeze supercooled water in the hurricane, thereby disrupting its structure. Nice idea, but unfortunately there was not enough supercooled water for the silver iodide to act upon, so the project was a failure.

NUKE A HURRICANE

There is always someone out there for whom a nuclear blast is the solution, in this case for stopping a hurricane in its tracks. The problem is that the energy locked up in a hurricane dwarfs that of even the biggest nuclear bomb. In fact, an established hurricane releases as much heat energy every 20 minutes as a 10-megatonne nuclear device.



BOMB A VOLCANO



Before his exploits in WWII, US General George Patton fought a battle with the lava flowing from Hawaii's Kilauea volcano, which threatened the town of Hilo in 1935. The plan was to disrupt the lava channels and tubes that carried fresh lava to the flow front.

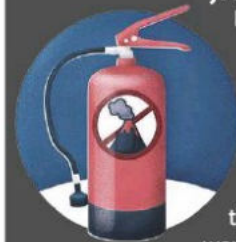
Unfortunately, the bomb craters just filled up with lava. Hilo was saved, but only because the eruption had coincidentally stopped.

STOP A TSUNAMI IN ITS TRACKS

Mathematician Dr Usama Kadri thinks that tsunamis could be weakened with deep-ocean acoustic waves. These naturally occurring waves travel at the speed of sound – if they could be focused on a tsunami, they could reduce its height. But translating it into practice would likely prove impossible.




JUST ADD WATER



During 1973's eruption of the Eldfell volcano on the Icelandic island of Heimaey, a lava flow that was threatening to destroy the harbour was kept at bay for five months by spraying it with water, causing the flow front to solidify. Luckily, the lava was slow-moving and there was unlimited water. If the eruption hadn't stopped, the harbour would eventually have been overwhelmed.

HOW TO STOP AN

EARTHQUAKE



Portland, Oregon, lies near a geological fault, making it susceptible to earthquake damage like this

As the planet's population becomes more urbanised and the number of people living in megacities in earthquake zones grows, the threat from seismic activity rises. So far this century, earthquakes have taken 750,000 lives, and it's only a matter of time before a single quake causes a million deaths.

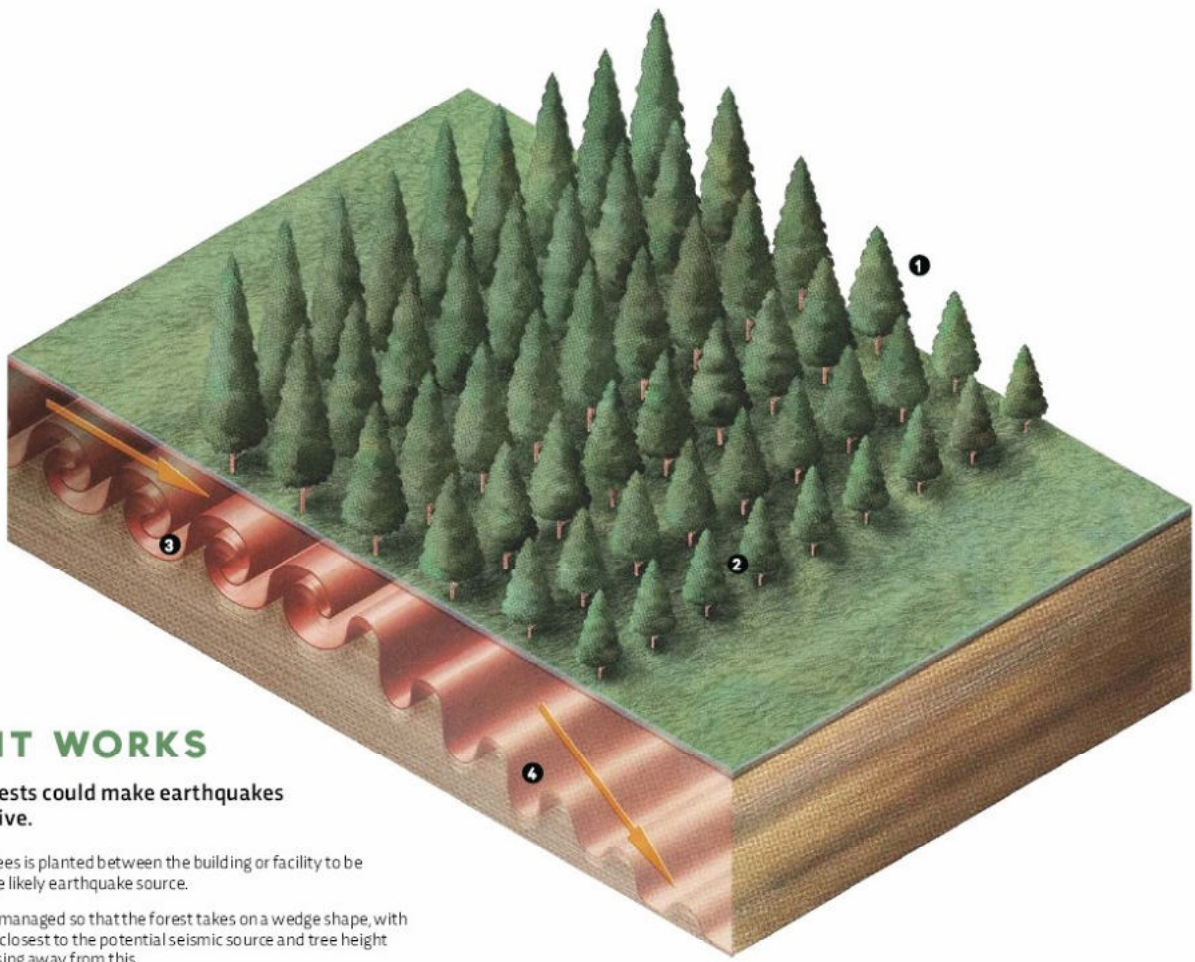
Seismologists have been trying to predict earthquakes for more than 50 years and are no closer today. It would solve all our problems, however, if we could just stop them happening. One possible way of doing this would be to pump water into a fault so that it lubricated the fault plane, allowing it to move more easily and frequently. This would generate small, non-damaging quakes, rather than storing up all the strain for a 'big one'. Fault lubrication is, however, largely untested and hit-and-miss. Stopping an earthquake in this way is clearly a long way off, and may never be feasible at all.

But there is another way of using tech to protect buildings, and that is by shielding them from damaging seismic waves. Leaders in this field are Dr Sébastien Guenneau at Marseille's Fresnel Institute and Dr Stéphane Brûlé at the geoengineering company Ménard. In 2012, at the foot of the French Alps, they drilled a line of boreholes arranged in such a way that

the properties of the soil were changed so that incoming earthquake waves would be reflected. By generating artificial earthquake waves using a piece of ground-vibrating kit, they were able to demonstrate that seismic energy crossing the line of boreholes was slashed by up to 80 per cent.

Guenneau, Brûlé and co-workers propose that modifying the density and other properties of the soil around a building could form a shield that stops potentially destructive seismic waves from reaching it. And that isn't the end of it. While Guenneau admits that the seismic waves reflected by the shield could be a problem, damaging any buildings that lie in their path, he tantalisingly goes on to reveal that "we have looked at an alternative solution – so called invisibility cloaks for seismic waves".

There has been plenty of research in recent years on cloaking devices that seek to make people or objects invisible by bending the light around them, but could this work for earthquake waves? Guenneau thinks it can, and already has the theory worked out. He believes that judiciously placed concrete pillars dug into the soil could act as an effective seismic cloak, and might only need some modification in the design of building foundations. But according to Guenneau, there is an environmentally friendly way too. "I have



HOW IT WORKS

Managed forests could make earthquakes less destructive.

- ❶ A barrier of trees is planted between the building or facility to be protected and the likely earthquake source.
- ❷ Tree height is managed so that the forest takes on a wedge shape, with the highest trees closest to the potential seismic source and tree height gradually decreasing away from this.
- ❸ When an earthquake takes place, potentially destructive Rayleigh waves are generated, which travel close to the surface.
- ❹ The forest resonates in response to the arrival of the Rayleigh waves, converting them into less destructive shear waves which travel down into the Earth's interior where they can do no harm.

been involved in some work on the conversion of Rayleigh waves into downward-propagating shear waves, thanks to a forest of trees of varying heights," he says. Rayleigh waves travel close to Earth's surface rather than through the deep interior, and are some of the most destructive of all seismic waves. If specially planted forests, like the ones Guenneau is experimenting with, can transform the Rayleigh waves into a less destructive type of wave and divert them down into the ground, then they provide the perfect green solution: a seismic cloak that protects buildings and sucks carbon out of the atmosphere.

On the grandest of scales, future cities could be designed to control the passage of seismic waves through them. Seismic energy travelling through an urban space can be increased or reduced as a consequence of the form and arrangement of skyscrapers. According to a recent paper by Brûlé, Guenneau and others, specially designed curved streets or blocks of buildings could guide incoming seismic waves so they are directed around sensitive areas in the city, such as power plants, hospitals, stadiums and schools.

There is still a lot of research needed before these techniques can be used to protect against real earthquakes, but if they prove to be successful then the implications are huge. 🍳

Sensors sitting on top of concrete blocks measure how boreholes drilled into the ground can affect seismic energy



Prof Bill McGuire is a professor of geophysical and climate hazards at University College London and author of *Waking The Giant*.



ALERT!
CONTAINS
PLOT
SPOILERS

STRANGER THAN FICTION

Alex Garland's debut film about artificial intelligence, *Ex Machina*, blew our minds. On the eve of the release of his next film, *Annihilation*, we caught up with its science consultant **Adam Rutherford** to find out how it's stranger, scarier and smarter than its predecessor...

Words: **Daniel Bennett**



Adam Rutherford presents BBC Radio 4's *Inside Science*, which answers the big questions about the science that's changing our world bit.ly/inside-science. *Annihilation* will be out on Netflix in spring.



How involved were you in the creation of *Ex Machina* and *Annihilation*?

For *Ex Machina*, Alex Garland [the director] described it as a sanity check. I was there to look at how scientifically plausible the dialogue was. We wanted to make sure that there weren't any of what we would call '2012 moments'. In the film *2012*, the Earth is being destroyed by some sort of cosmic event and there's this key moment in it when your cookie cutter scientist looks at the screen and says something like

"the neutrinos are mutating". Of course, this is a hilariously meaningless phrase.

Scientific verisimilitude is important to Alex, even more so than to me. In fact, there were lots of times during both films where I said, "I'm not sure this matters," but he wanted both films to reflect the way we talk about science and the kinds of breakthroughs that are being made.

How did you land such a great gig?
I'd worked on a couple of films

already. I'd worked on *World War Z*, *The Kingsman* and with Björk on her movie of *Biophilia*.

I got a call from a friend who said they knew someone who was writing a screenplay that needed a scientific hand. I said I'd help. Then five minutes later I got an email from Alex and I spat my coffee out. We've worked together ever since.

What sci-fi do you love?

I've got pretty catholic tastes, to be honest. The sci-fi that I love in ●

● movie form is pretty predictable. I find that there isn't much that's super high quality, so I like films like *Blade Runner* and *Aliens* but also *2001*. I adore *Solaris*, both versions. I enjoy films driven by ideas, but they need to have good plots, great performances and good special effects, so I wouldn't want to restrict myself. One of the reasons *Ex Machina* worked so well is that really it's a horror film, and you don't realise it's a horror until about three-quarters of the way through. *Annihilation* has a similar effect.

I've worked on other alien movies before and the joke in Hollywood is that the studio always says "give me something I've never seen before". That's a hard thing to do, but I guarantee you've never seen anything like what's in *Annihilation*.

Jeff VanderMeer's novel that inspired this film is an eerie, dream-like experience. How did you balance recreating this with the film's science? It's all in the writing, really, and in the power of the visual effects. Both the book and the film look at the nature of mutation and self-destruction. But when it came to putting these ideas on screen we had to think specifically about how these mutations might manifest themselves.

The trailer reveals these bizarre cross-species mutations the scientists come across, like a crocodile with shark's teeth, and plants in humanoid structures. The story just requires these things to be creepy. But such is Alex's interest in the science that he was quizzing me about how it could happen. On the one hand the answer is no, that's not really how biology works, but on the other, if it did happen then we looked at all the means by which [these mutations] could occur. We specifically talk about Hox genes, for example, which are the body plan genes. Alex has this desire to not have things that are scientifically ridiculous, to have the dialogue talk about the nature of cell biology or genetics in such a way that it creates a strong foundation for the film.

What about Natalie Portman's character of the biologist, whose



ALEX GARLAND'S PREVIOUS FILM, THE SMART SCI-FI THRILLER *EX-MACHINA*, RECEIVED BUCKETLOADS OF AWARDS AND NOMINATIONS – WE HAVE HIGH HOPES FOR *ANNIHILATION*

"I worked with all of the cast. They all wanted to know how a scientist would react – what they would think, how they would feel, and all of that is buried in their amazing performances"

ADAM RUTHERFORD

background is closest to your own. How involved were you in her direction?

I worked with all of the cast. They all wanted to know how a scientist would react – what they would think, how they would feel, and all of that is buried in their amazing performances.

Whenever I've worked with actors, I've been asked loads of questions that no one in real life is ever interested in. All of a sudden you're opposite Natalie Portman who's asking me "why are you like this?". It's a weird position to be in for sure. In a sense, I don't necessarily think that scientists have a different mindset to anyone else. Of course, you might lean in certain directions, but it's nice to see a bunch of scientists on screen represented as people with a bunch of personality problems. I can't praise their performances enough.

In the book, the biologist recalls a

starfish – the destroyer of worlds – that fascinated her so totally, that it, in part, drew her into a career in biology. Did you ever have an engram like that?

I was clearing out some old photos the other day, and we came across a photograph of me in my bedroom and on the wall there are two visible pictures. One is a picture of Han Solo kneeling above the tauntaun in *The Empire Strikes Back* and the other is a cut-out picture of a nautilus from David Attenborough's book from the television series *Life On Earth*. I was never pushed in a particular direction but it was clear from that photo, 40 or so years after it was taken, that my interests are almost exactly as they were as a young boy. I suppose in both pictures there's an interest in the unreality of science and science fiction. The nautilus, which is this totally weird creature, is completely alien and bizarre. Maybe that is



ANNIHILATION IS BASED ON THE FIRST BOOK IN THE SOUTHERN REACH TRILOGY. IT SEES FIVE WOMEN EMBARK ON AN EXPEDITION TO A REGION CALLED AREA X, WHERE NATURE WORKS IN STRANGE WAYS...

my equivalent of the biologist's destroyer of worlds.

Science often is as strange as science fiction...

The more we understand about ethology [the study of animal behaviour] the more we realise how little we really know. We're so anthropocentric in the way we understand biology. In actuality, animal behaviour is so baffling and so alien to our sensibilities.

I have just written a whole section in my new book on sex in nature. The diversity of non-reproductive sex behaviour is astonishing. We humans spend a lot of time having sexual relations that are not really capable of producing babies. I ran some of the numbers on it for the book and estimated that the proportion of sex that could result in a baby is actually something like 1 in 1,000. You would presume that cannot be the same in nature. The number should lean more towards the act of reproduction. But the answer is no, not in the slightest. Homosexual behaviour is almost universal in animals. Necrophilia is extraordinarily common. I could go on and on.

You know, some estimates suggest that 9 out of 10 sexual encounters in giraffes are male to male. That says something about how evolution uses the tools in front of it. Sex is clearly important, or else it wouldn't be almost universal in animals, but what evolution has done in the one or two billion years since sex evolved is turn

it into a tool for a bunch of stuff of which we have almost no understanding. Yet we transpose our own behaviour and assume there's a shared evolution route or a shared purpose on convergent behaviours. The truth is, I think we just have no idea. We don't know what male giraffes are doing when they have sex. It's homosexual, yes, but is it the same as homosexuality in humans? Who knows?

So are some things just unknowable?

I'm an empiricist, so I think all things are knowable. We'll get there. We're just incredibly good at applying anthropocentric views to this type of behaviour. The scientist, George Murray Levick, on Robert Scott's fatal trip to the Antarctic – 1910 to 1912 was the expedition – was the first person we know of to document necrophilia and aggressive sexual coercion in penguins. He described it as deviant and appalling behaviour, and as such it's expunged from the record. He took a very Edwardian view of all this interesting behaviour. In reality, it has nothing to do with necrophilia as a psychological abnormal pathology – we have no idea why they're doing this.

What I am saying is that I think the whole point of science is to remove ourselves from our understanding of nature – that's why we invented the scientific method. We have a minuscule view of the Universe as it actually is compared to how we perceive it. The whole reason we

invented the scientific methodology is to cancel that out. I think we're better at it and have a better understanding than we've ever had. But I just think we get blasé because we see David Attenborough documentaries and we have an industrial version of biology these days.

We think that we are at the point of just filling in the details because we have figured out evolution. But the truth is that almost all nature is unobserved and has been unobserved through history.

There's been a wealth of thought-provoking science fiction recently. Do you think that reflects how fast our world is changing?

I'd love to say it might be a reflection of some sort of societal ideas emerging. But honestly, I think it's a reflection of Hollywood, which is a business. I think *Ex Machina* was a part of this, because it clearly showed that 18-rated, intellectually robust science-fiction films make a load of money.

And what happens after films like *Ex Machina* is that you see a wave of them being released. This could change because *Blade Runner 2049* bombed, and as a result I expect we could see fewer highbrow films in the coming years, but we'll see. It's show business. The next project that I've been working on is going to be on TV, it's almost like companion piece to *Ex Machina*, it's sort of set in the same world – but you'll have to wait for details. 🕒

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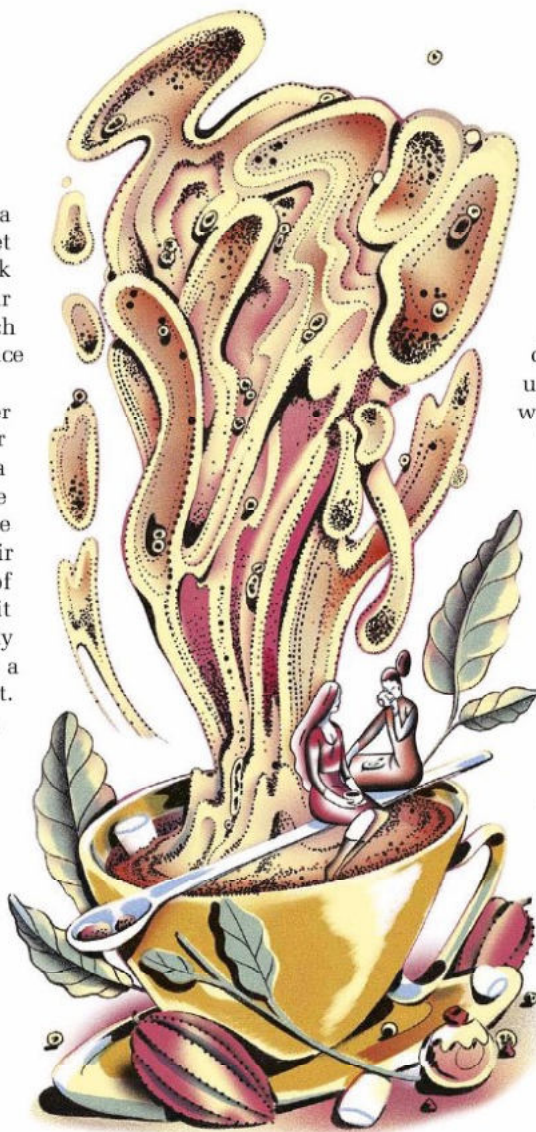
HELEN CZERSKI ON... **COCOA POWDER****"WHY IS COCOA HARD TO DISSOLVE, AND WHAT'S THE BEST WAY TO MAKE THE PERFECT HOT CHOCOLATE?"**

Almost everyone loves a mug of hot chocolate. Yet this silky, elegant drink gets its delicious flavour from cocoa powder, which is a bitter, gritty and unpolished substance – a classic ugly duckling.

The awkwardness of cocoa powder is most obvious when you try to stir it into liquid, such as milk or vanilla essence. It just doesn't want to go. The powder somehow perches on top of the liquid without getting wet. You can stir for ages, but when you push a clump of powder into the liquid with a spoon, it disappears only briefly before cheerfully popping up to the surface, releasing a puff of dry cocoa just to prove its point. But get the mixing right and silky hot chocolate awaits. What's the secret of the transformation?

We often talk about 'dissolving' cocoa powder into milk, but cocoa doesn't ever dissolve. It's mostly made up of dietary fibre and starches, with only 10 to 12 per cent cocoa butter and a few other components. All of that means that it's insoluble in water. But the solid lumps of cocoa powder are around 0.01mm in diameter, which is slightly too small for our tongues to detect any graininess. So as long as the cocoa particles are dispersed evenly in a liquid to form a suspension, it feels smooth to us. One teaspoon of cocoa powder has about two billion particles in it, and they all need to be separated and coated in liquid. This is where the fun starts.

Cocoa is hydrophobic, which means that it resists getting wet. But the bigger problem is that cocoa particles tend to stick to each other quite easily, making loose clumps. Cocoa itself is more dense than water and so you might expect it to sink, but there's so much air in the clumps that they float. Each clump might also develop a thin waterproof shell, because the starch



in the cocoa on the outside of the clumps will absorb a tiny bit of water and form a thin gloopy layer which stops water from penetrating any further inwards. The only way to disperse the cocoa evenly is to break up these clumps, and there are two weapons in your arsenal.

The first is to pick your liquid well. Hot water/milk will penetrate the clumps more easily than cold, because hot liquid is slightly more runny and doesn't repel the cocoa quite as much. And full-fat milk is better than water or skimmed milk, because the fat droplets will surround the cocoa particles and that helps split them off from the rest of the clump.

But the real trick is to break up the clumps by stirring in a particular way. You need 'shear', which is a sideways force: like pushing your flat hand down hard on a table and then moving it along the surface. This is why people add a small amount of liquid and stir the cocoa into that first – this mixture is thicker and it's harder for clumps to slide out of the way and avoid being broken up. Vigorous stirring works too, but it won't help much if the mixture is too wet. And once the particles are all in direct contact with the liquid, your problem is solved because they won't clump together again.

So here's the scientific method to get it right: squish your cocoa powder sideways into a small amount of warm full-fat milk to break up the lumps, and then gradually add the rest of the liquid. And then the lovely chocolatey potential of the cocoa powder will be all yours, free of lumps and frustration. Just thinking about it brings on the urge to experiment. Happy stirring! ☪

Dr Helen Czerski is a physicist and BBC presenter. Her latest book is *Storm In A Teacup* (£18.99, Transworld).

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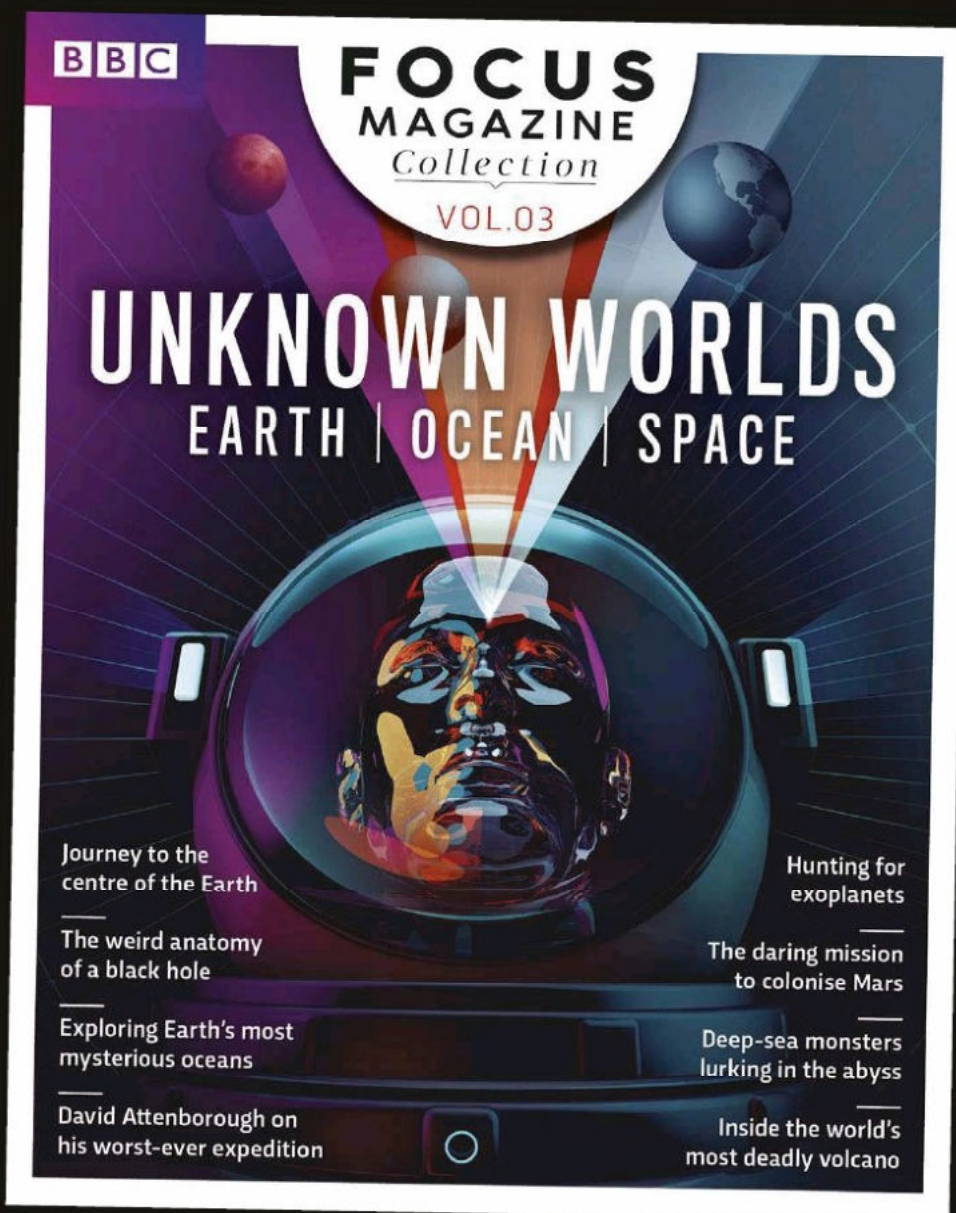
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YOUR QUESTIONS ANSWERED

MARCH 2018

EDITED BY JAMES LLOYD

Do caterpillars have a sex before they become butterflies?

ADRIAN LEWIS, EXETER

The sex of a caterpillar is fixed at the moment the egg is fertilised, but most species don't show any sex-specific features until they turn into butterflies. The immature reproductive organs are still present in the larval stage though, and in a few species with translucent bodies, you can see the red or dark yellow testes of the males. **LV**





Why does food rot?

JACOB HIPKISS, SOUTHWELL

As cells die, their membranes degrade and enzymes start leaking out. The cell digests itself, then neighbouring cells, and the process cascades. Without any immune response to stop them, bacteria and fungi will also begin eating the food and multiplying. As they munch away, they alter the texture of the food and release waste products that change the taste. There are purely chemical rotting mechanisms too, like fat oxidation, which makes it taste rancid. **LV**

IN NUMBERS

90m

The cost in US dollars of the Falcon Heavy rocket launch.

10,000

The age of 'Cheddar Man', Britain's oldest near-complete skeleton, whose DNA revealed he had dark skin and blue eyes.

15

The per cent that memory can be improved by, using electric pulses to the brain.



Where is the centre of the Universe?

DARREN GROOM, WEST BROMWICH

As the Universe may not have a physical edge, there is no sense in the idea of an 'absolute' position. Hence, it is meaningless to think of the 'centre' of the Universe; something of infinite extent has no 'centre'. Imagining the 'centre' as the point at which it began is also meaningless. The Big Bang happened everywhere at once and the Universe has been expanding ever since. Every point can be regarded as being at the 'centre' of this expansion. So, the centre of the Universe is nowhere, and everywhere! **AGU**

Is plastic currency more or less hygienic than its paper equivalent?

PETER WALTON, LANCASHIRE

A 2013 study (published before the UK switched to plastic banknotes) found that the polymer currency used in Romania allowed MRSA superbugs to survive for 24 hours, compared with just three hours for paper notes. But subsequent studies on the new polymer £5 note have found that harmful germs are much less likely to stick to the plastic in the first place. **LV**



How old is dyslexia?

LYDIA RAE STEPHENSON, STAFFORDSHIRE

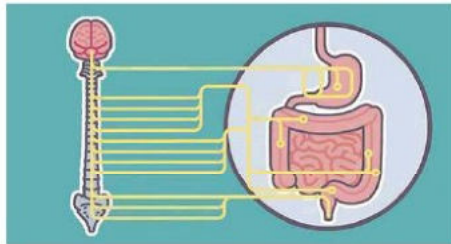


Many sources will tell you that the first case was reported in 1896 by the English family doctor W. Pringle Morgan, who described a 14-year-old boy called Percy with "word blindness". Morgan noted how, despite his intelligence, Percy struggled to read. However, the first use of the term 'dyslexia' was actually by the German ophthalmologist Rudolf Berlin in 1887, in his case report of a boy with problems learning to read and write. **G**

...I FEEL HUNGRY?

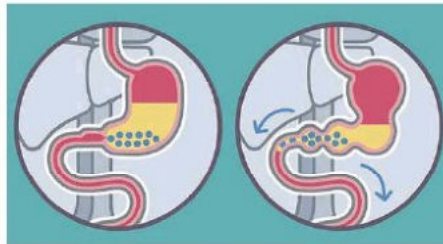
TOM RUSSELL, BIRMINGHAM

Hunger is a complex sensation that is only indirectly linked to the need for food. Humans are opportunistic omnivores that have evolved to take advantage of sustenance whenever it is present. The sight or smell of food can trigger hunger, and so can even just imagining it. Your body also needs time to prepare for digestion and many of the related hormone changes are driven by your body clock. So you'll feel hungry at lunchtime, whether you need to eat or not.



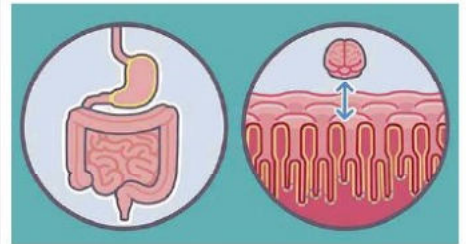
1. Vagus nerve

This sends signals to the brain about how full or empty your stomach is, as well as the different nutrients present in the intestines.



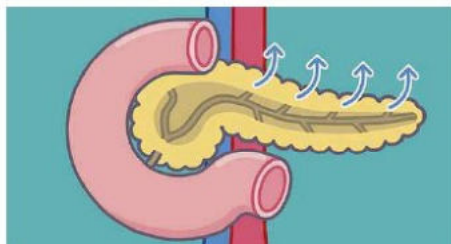
2. Stomach

When your stomach has been empty for two hours, it begins contracting to sweep remaining food into the intestines. This rumbling is called 'borborygmus'.



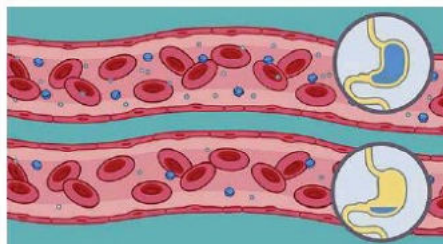
3. Gastrointestinal tract

Cells in the stomach and intestine produce ghrelin, a hormone that triggers feelings of hunger. Higher ghrelin levels are associated with obesity.



4. Pancreas

As usual mealtimes approach, your pancreas secretes insulin to prepare for an expected intake of sugar. This causes a pre-meal dip in blood glucose.



5. Blood

Levels of key nutrients in your blood – including glucose, amino acids and fatty acids – are at their lowest concentrations when you are hungry.



6. Brain

Hunger increases your impulsiveness and reduces your ability to make long-term decisions. This is why you shouldn't shop on an empty stomach.



Do London plane trees actually absorb pollution into their bark?

LUCAS MOORE, SWANSEA

They don't absorb it, but pollution particles do get stuck to the bark and trapped in the hairs on the leaves. A 2011 study estimated that every year, trees in Greater London remove 850 to 2,000 tonnes of PM10 pollution particles, which are the type considered harmful to humans. Plane trees do emit isoprene though, which combines with nitrous oxide in car exhaust emissions to produce harmful ozone. Luckily, this only reaches dangerous levels in temperatures above 30°C, which are rare in the UK. **LV**

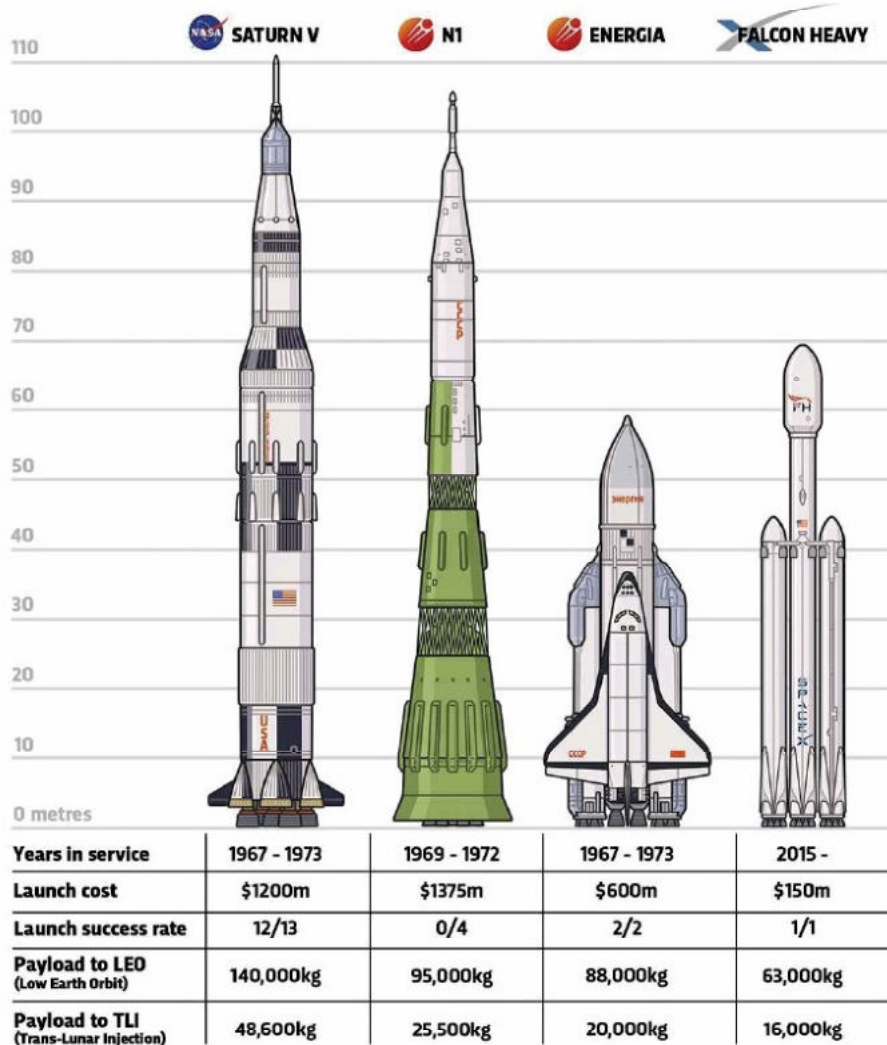
What is exotic matter?

LIAM FARMER, BIRMINGHAM

It's the generic name physicists give to matter with weird properties. Exactly how weird depends on the area of physics. For example, those working in cryogenics – the study of ultra-cold temperatures – work with so-called superfluids, isotopes of helium whose quantum properties allow them to defy gravity, escaping from containers by creeping up and over the walls. But the oddest forms of exotic matter are those investigated by cosmologists, such as the true identity of so-called dark matter. This is widely considered to pervade galaxies, and is thought to be some form of exotic particle quite unlike the protons, neutrons and electrons making up standard matter. **RM**

How does SpaceX Falcon compare to other rockets?

ETHAN VAUGHAN, CHESHIRE



Is there any point to finding ever-bigger prime numbers?

JOE CAIRNS, EDINBURGH



On 26 December 2017, the largest prime number yet found – code-named M77232917 and over 23 million digits long – was uncovered by a member of a global team of computer enthusiasts. But apart from brief fame and a cheque

for \$3,000, there seems little point, as even the Ancient Greeks knew that there's an infinite number of the things. The only real practical value comes from using the search algorithms to give new computer hardware a workout. **RM**

Do plants think?

BEN CHELSKI, COLCHESTER

Plants don't have a central nervous system, so thought (as we normally define it) isn't possible. But plants can sense their environment, respond to insect attacks and are even capable of limited movement. These reactions are driven by chemical signals – rather than nerve impulses – so it's more like your immune system or unconscious hormonal responses, than conscious or deliberate thought. **LV**



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Are there any quantum effects that we can see day to day?

LIAM FARMER, BIRMINGHAM

As they govern the behaviour of atoms, quantum effects underpin everything from the ability of plants to turn sunlight into chemical energy to the behaviour of semiconductors in microchips. Their influence is, however, usually subtle and hard to see directly. Perhaps the most spectacular demonstration of quantum effects, pure and simple, is a magnet. Despite its familiarity, magnetism is actually impossible without quantum effects, which are needed to explain the necessary behaviour of atoms. For example, the ability of a simple bar magnet to pick up a needle is the result of the so-called Pauli Exclusion Principle, a key component of quantum theory that dictates how electrons are arranged. **RM**



Do solar panels work better on hot days?

LIAM FARMER, BIRMINGHAM

Surprisingly, they perform worse as the temperature rises! Solar panels work by using incoming photons to excite electrons in a semiconductor to a higher energy level. But the hotter the panel is, the greater the number of electrons that are already in the excited state. This reduces the voltage that the panel can generate and lowers its efficiency. Higher temperatures also increase the electrical resistance of the circuits that convert the photovoltaic charge into AC electricity. Modern hybrid solar panels are designed to suffer less from the heat, but they can still lose 10 per cent of their rated efficiency on hot days. **W**



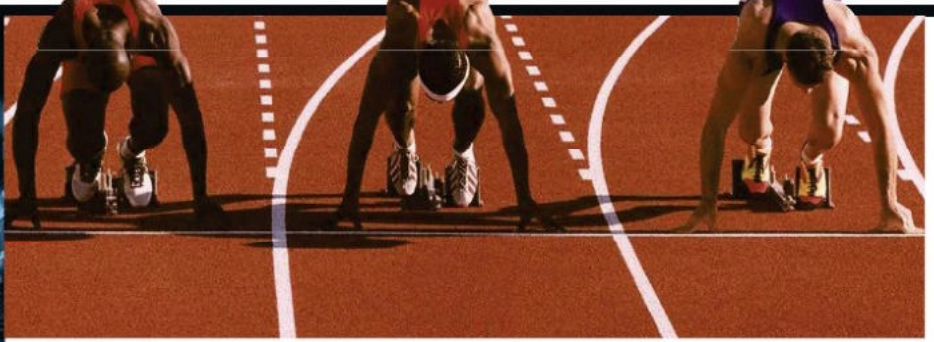


Is there a way that the internet could be switched off worldwide?

MARK HURST, WIGAN

No. This is like asking “could you stop every river in the world at once?”. You can dam or divert individual streams, but it is virtually impossible to block them all at once, because the water always tries to find a new route downhill. Likewise, the internet is a huge and complex structure operated by a mixture of government and commercial bodies – as well as billions of private individuals. There isn’t a single connection point that all the data flows through, and the internet protocol was specifically designed so that data finds a route around parts of the network that are down.

But the internet isn’t entirely invulnerable, either. In 2011, during the Egyptian Revolution, the Egyptian government ordered the four national internet service providers to turn off the Domain Name System (DNS) and alter the Border Gateway Protocol of their servers. This prevented any internet traffic in or out of the country. The UK has the legal authority to do the same thing in the event of a national crisis, but this power has never been used. And if the US for some reason ordered Microsoft, Apple, Facebook and Google to turn off their servers, the internet would be as good as shut down for most of us. **lv**



What's the speed of thought?

GEETHU THOMAS, SURREY

Scientists have approached this difficult question by timing how long it takes us to become consciously aware of sensory information. By some estimates, we can experience sensory stimuli that’s presented for as little as 50 milliseconds (about one-twentieth of a second). It is thought that our brains can, in fact, respond to information that’s much briefer than this, lasting less than a quarter of a millisecond. In

terms of sensing and then responding, a good measure is the sprinter reacting to the starting gun, which can be done in about 150 milliseconds. One limiting factor is how long it takes information to travel down our nerve pathways. In the 19th Century, Hermann von Helmholtz estimated this to be 35 metres per second, but we now know that some well-insulated nerves are faster, at up to 120 metres per second. **q**

Why do I remember something better if I read it out loud?

JONATHAN WARTON, HEREFORDSHIRE

There are at least two possibilities – one is that it helps to hear the information in your own voice, the other is that there’s something memorable about the act of speaking the words. A clever study put these two explanations to the test recently. It compared participants reading words aloud to listening to earlier recordings of themselves saying words, using a memory test. The findings suggested that both the act of speaking, and hearing oneself, assist memory – the former because it’s a more active, involved process than silent reading, and the latter because hearing oneself speak makes the information more personally salient. **q**



WHAT IS THIS?



Rocket launch lights up the heavens
This eye-catching spectacle could be seen in the skies above Arizona and California on 22 December 2017, following the launch of a SpaceX Falcon 9 rocket from Vandenberg Air Force Base. The phenomenon was caused by the light of the sunset hitting the rocket's condensation trail and illuminating the early-evening sky as the Falcon 9 carried communications satellites into space.

WHO REALLY DISCOVERED?

HUBBLE'S LAW

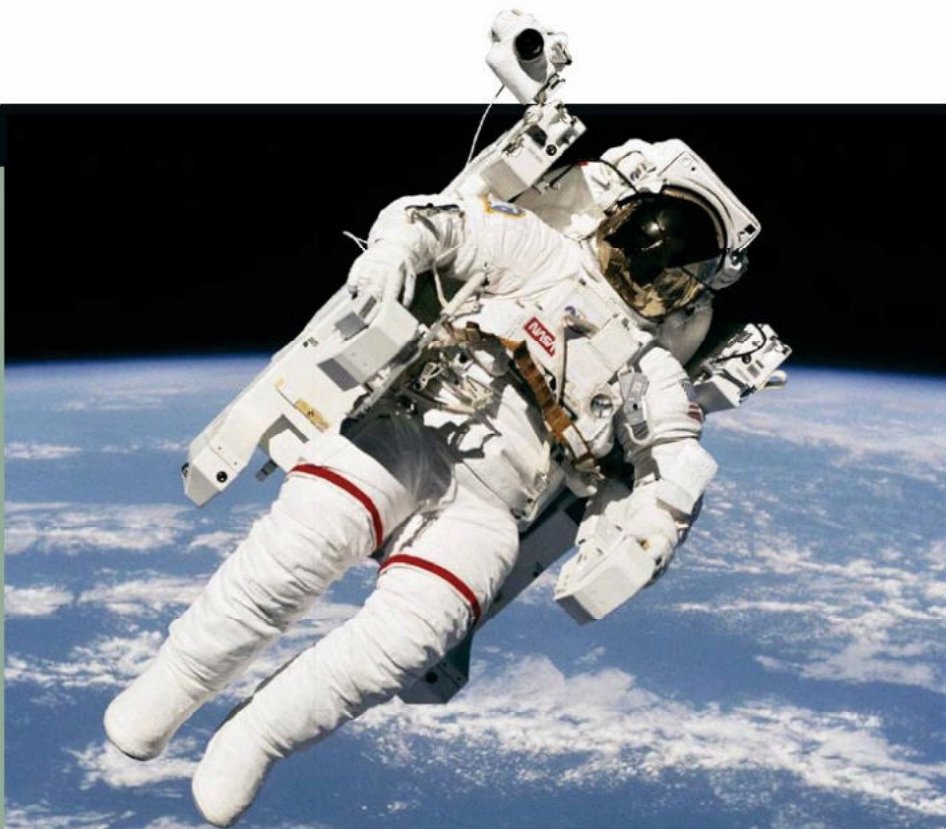
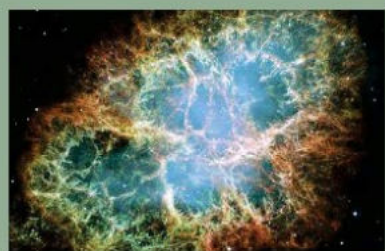
EDWIN
HUBBLEGEORGES
LEMAÎTRE

In 1929, one of the most astounding discoveries ever made was published by the American astronomer Edwin Hubble. Using observations of distant galaxies, he showed that the Universe is expanding. Not only that, but it is doing so in a specific way, with galaxies racing away from each other at speeds that grow with their increasing distance from each other.

Now known as Hubble's Law, his principles remain at the core of cosmology, allowing scientists to calculate the age of the Universe. Yet by rights it should really be known as Lemaître's Law, after the Belgian priest, astronomer and academic who both predicted it and demonstrated its validity two years before the publication of Hubble's work.

Originally trained in mathematics and astronomy, Georges Lemaître was an expert in the cosmic consequences of Einstein's theory of gravity: General Relativity. In 1927, he published a paper showing that Einstein's theory implied that the Universe could expand. He then used new observations of the distance and speed of galaxies to support his mind-boggling claim.

Published in a relatively obscure Belgian journal, Lemaître's breakthrough was unknown to Hubble, who made the same discovery independently. Being more interested in science than glory, Lemaître declined to take a stand over priority, and so the law carries Hubble's name today. **RM**



Why do astronauts always use white suits?

GEETHU THOMAS, SURREY

Space is a dangerous environment and presents extremes of both hot and cold for the human explorer. To allow spacesuit cooling (and heating) systems to work most efficiently, they are made of material that reflects much of the

incident radiation (mostly sunlight) that falls on them; hence, they are white. Another reason for using white material is that this helps astronauts to be visible to crew members, even in the darkness of the Earth's shadow. **AGU**



Can humans hibernate?

RUCHA POTDUKE, BERKSHIRE

There are apocryphal stories of medieval Russian peasants surviving the winter famine by spending six months almost constantly asleep. But true hibernation is more like extended hypothermia than sleep and there are lots of serious side effects. Hibernating mammals accumulate mucus in their lungs and suffer memory loss and suppressed immune systems. Medically induced hypothermic comas of up to two weeks have been used to treat brain injuries, but tests on healthy humans are a long way off. **W**

Why do we have a 'wind chill factor'?

MARK WADDELL, LOWESTOFT

On cold, windy days, weather forecasters often warn that the stated temperatures are misleading, as it will feel much colder due to 'wind chill'. First devised in the 1940s, the wind chill factor was based on the effect of wind speed on heat-loss from cylinders of water. By the early 2000s, this had become the more accessible concept of the difference in temperature resulting from exposure to the wind. So, for example, 4°C above freezing is said to feel more like -2°C in a 40km/h breeze. But the idea of wind chill can be misleading. No matter how hard the wind blows, it can't chill things below air temperature – it simply increases the rate of heat loss. Plus wind chill calculations leave out key factors such as the constancy of the wind and whether the Sun is shining. **RM**

		Air temperature (Celsius °C)									
		5	0	-5	-10	-15	-20	-25	-30	-35	-40
Wind speed (km/h)	10	3	-3	-9	-15	-21	-27	-33	-39	-45	-51
	20	1	-5	-12	-18	-24	-31	-37	-43	-49	-56
	30	0	-7	-13	-20	-26	-33	-39	-46	-52	-59
	40	-1	-7	-14	-21	-27	-34	-41	-48	-54	-61
	50	-2	-8	-15	-22	-29	-35	-42	-49	-56	-63
	60	-2	-9	-16	-23	-30	-37	-43	-50	-57	-64
	70	-2	-9	-16	-23	-30	-37	-44	-51	-59	-66
	80	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67
	90	-3	-10	-17	-25	-32	-39	-46	-53	-61	-68
	100	-3	-11	-18	-25	-32	-40	-47	-54	-61	-69
Danger of frostbite		Low risk				Within 30 minutes		Within 5 to 10 minutes		Within 5 minutes	

QUESTION OF THE MONTH

Could we use radiometric dating on 'Oumuamua?

SIMON BARTLETT, LEICESTER

Discovered last October, 'Oumuamua was the first object of interstellar origin found within the Solar System. It is a fascinating object; an elongated red rock about 230 metres long, by 35 metres wide, but its origin is a complete mystery. Radiometric dating has been used very successfully to date meteorites found on Earth and presumably could be useful for dating 'Oumuamua too. For such a study the rubidium-strontium or

samarium-neodymium isotope ratios would normally be measured by mass spectrometer. Assuming that a sample of 'Oumuamua could be returned to Earth uncontaminated, that there are sufficient quantities of the required isotopes present and that no physical processes have altered the isotope ratios since formation, a reasonable estimate of the age of 'Oumuamua should be possible. **AGU**

WINNER!

Simon Bartlett wins two YubiKeys, (worth £28.70 each, yubico.com). This USB-style stick allows you to increase online security by using both your standard passwords and the YubiKey when logging in to social media and email.



NEXT ISSUE:

How did the Romans do maths?

Why do tattoos fade?

Do other animals get allergies?

Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

MARCH 2018

EDITED BY JAMES LLOYD

01

THE MAN ENGINE
UK TOUR, FROM 31 MARCH
THEMANENGINE.CO.UK

SEE THE MAN ENGINE

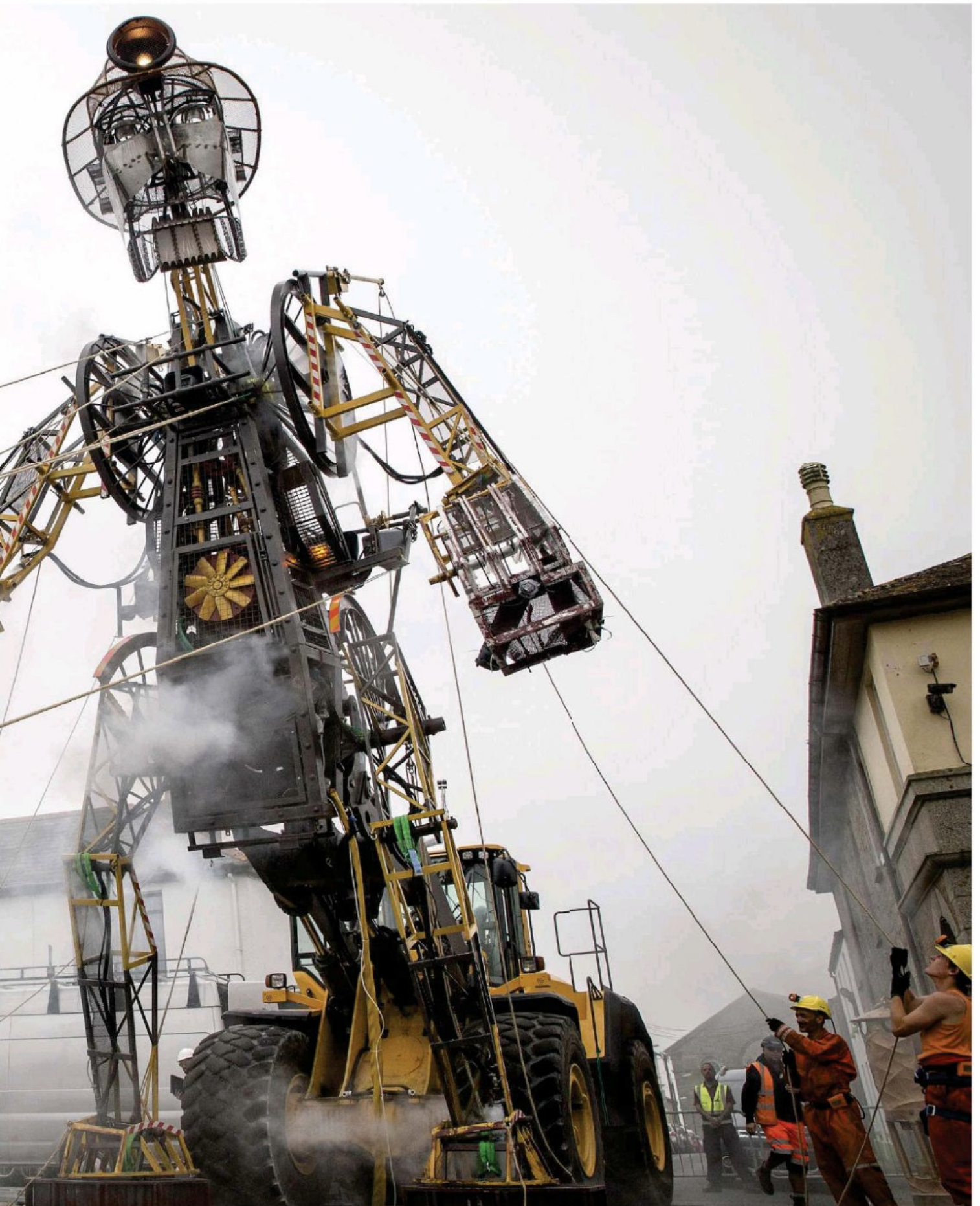
Behold The Man Engine! Having initially wowed crowds across Cornwall in the summer of 2016, the largest mechanical puppet ever constructed in Britain heads out on a UK tour this month.

The 11m-tall, 4-tonne miner was built to celebrate 10 years of the Cornish Mining World Heritage Site. On 31 March, his tour kicks off at the Geevor Tin Mine on the tip of Cornwall, before heading up through Devon, Somerset, South Wales, Shropshire, Yorkshire and Derbyshire. At each location, there'll

be both afternoon and evening events, which all include a show by The Man Engine. The 'Afternooners' have a more family feel, with mining-themed games and activities, plus the rousing sound of a local brass band, who'll also take part in The Man Engine show itself. Meanwhile, the 'Afterdarkers' promise an edgier spectacle, with an industrial soundtrack and explosive pyrotechnic effects. Turn over to find out more about how The Man Engine was brought to life.



PHOTO: LUKE BROWN



Q&A:

HAL SILVESTER

Lead designer of
The Man Engine



How was The Man Engine born?

In 2015, the Cornish Mining World Heritage Site put out a call for projects to celebrate 10 years since the local mining landscape was added to the list of UNESCO World Heritage Sites. The aim was to increase awareness of the region's industrial past, and The Man Engine was selected as the flagship project. We took him through western Devon and Cornwall in the summer of 2016, and we had an amazing response. In Penzance, 28,000 people turned up – more than the town's entire population! All the pasty shops had their best-ever days.

What's he made from?

He's mostly steel – the parts were all made from scratch, and we were inspired by the Victorian, cast iron aesthetic. He has a smoke machine on board, which uses compressed air to send out high-pressure jets of smoke from various parts of his body, giving an industrial, steam engine effect. But he has a modern look too: he's got one foot in the past and one foot in the future.

How does he move?

The Man Engine starts off each show crouched down, hidden under a shroud, and then he's raised up by a Volvo wheel loader. The puppeteering is done by 10 people dressed as miners, who pull on ropes to move his head and limbs, open

his mouth and blink his eyes. We wanted The Man Engine to be a puppet, not a robot, so you can really see the miners' exertion. The Man Engine also makes a lot of noise. People can get self-conscious if a puppet is silent: it's like seeing a bad mime artist. So as well as the jets of smoke, there are pistons, he stomps his feet, and there's a cement mixer in his belly with chains inside, which makes a rhythmic, clanking sound. This time around, there are also going to be pyrotechnic elements to conjure up imagery of smelting and molten metals. It's a really visceral experience.

What was the most challenging part of bringing The Man Engine to life?

He's 11 metres tall, but we wanted The Man Engine to be able to fit inside a shipping container so that we can one day take him overseas, to follow in the footsteps of the Cornish miners who

emigrated. We designed him to pack up really tight, like a 3D jigsaw puzzle. It was a challenge, but that's also one of the joys of the live experience: seeing him transform from this lifeless lump of metal into a giant.

What do you hope people will take from the experience?

Everywhere we're going on this UK tour, there's been mining or heavy industry. Even if you can't see it now, the heritage is still there, and the puppet helps people to connect with that. He gets people talking about the mining history in their own families, and he's inspiring an interest in engineering, too. Even though he's a big, clunky, steel giant, there's a sensitivity to him. He can look you in the eye, and we've had plenty of people in tears. That's one of the reasons why puppets are so powerful. You can see the strings, but when you suspend your disbelief, they come to life.



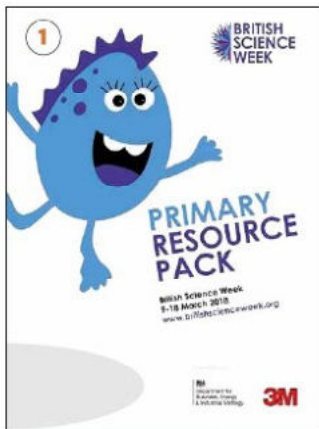
Operating The Man Engine is a tough job that requires the skills of 10 puppeteers

02

BRITISH SCIENCE WEEK
SCIENCE MUSEUM, LONDON
9-18 MARCH
BRITISHSCIENCEWEEK.ORG

CELEBRATE BRITISH SCIENCE WEEK

British Science Week returns this March for a 10-day celebration of science, technology, engineering and maths. Here are five ways you can get involved...



1. GET EXPERIMENTING

Fancy building a bug hotel? Creating some cheese from scratch? Or how about making your own Aztec poo? There are plenty of fun experiments to try in this year's free activity packs, with resources for early years, primary and secondary ages. The theme is 'exploration and discovery', so the aim is to get young people thinking about the everyday science that surrounds them. Turn to this month's supplement for even more experiment ideas.

2. CLEAN UP OUR BEACHES

Help tackle the plastic problem from the comfort of your home with this year's citizen science project, in collaboration with *The Plastic Tide*. This charity is using drones to map the pollution on beaches around the world. Participants will be asked to look at images snapped by the drones, tagging any plastics and litter they see. The aim is to train a machine learning algorithm to detect the plastics automatically, helping scientists



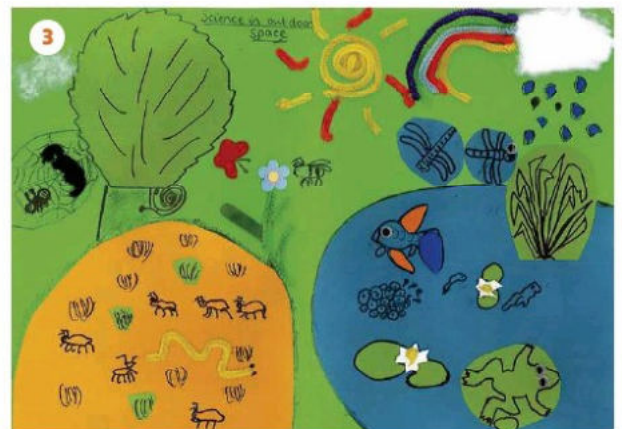
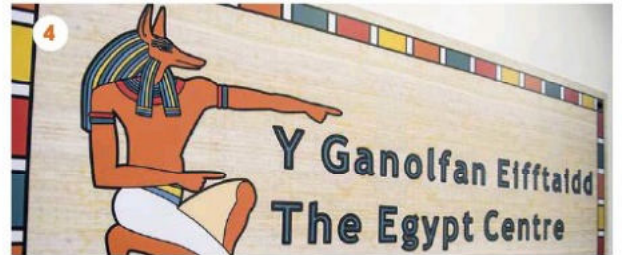
to track where the litter in our oceans goes. The target for British Science Week is 250,000 image tags, so get spotting!

3. DESIGN A POSTER

Flex your creative muscles and create a poster for the British Science Association's annual competition. The poster can be anything on the theme of 'exploration and discovery', and each school that's taking part can select five entrants for the UK-wide competition, with prizes up for grabs. Closing date for entries is Friday 6 April at 6pm.

4. PLEDGE AN EVENT

If you're organising something for British Science Week, you can now pledge your event so that it appears on a handy interactive map. But you don't have to pledge an event to get involved. There are oodles of happenings around the country, including a Science Treasure Hunt in Norwich, a Holograms & History event at Swansea's Egypt Centre, a celebration of animal



adaptations at ZSL Whipsnade Zoo, and a chance to create your own weather systems at the Scottish Fisheries Museum in Fife. Head to sciencelive.net/whats-on/ to browse the events near you.

5. RUN TO THE DEEP

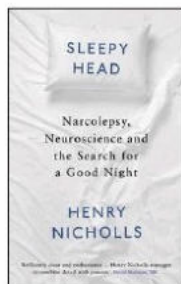
Following on from last year's race through the Solar System, the limber-limbed can this year run to the depths of the ocean floor. The 10km 'virtual race' can be run anywhere, anytime, and is free to enter. You just need a smartphone to download the app, which features audio commentary from the explorer Pierre-Yves Cousteau, son of the legendary marine conservationist Jacques Cousteau. As you run through your real-world surroundings, you'll be taken on a journey from the surface of the ocean to the Mariana Trench – the deepest known part of the oceans – meeting some strange creatures and exploring alien landscapes along the way.

03

UNDERSTAND NARCOLEPSY

SLEEPYHEAD
BY HENRY
NICHOLLS

OUT NOW (£16.99,
PROFILE BOOKS)



What exactly is narcolepsy?

Most people know that those with narcolepsy have an irresistible need to sleep at inappropriate moments during the day. This was my first symptom when I was diagnosed – I'd find myself dozing through tutorials at university and overdosing on caffeine. But that's probably the least interesting of the symptoms. Most people with narcolepsy also experience cataplexy, which is where the emotional centre in the brain causes a sudden loss in muscle control. It's the same process that happens during sleep to stop you acting out your dreams, but during the day, it can mean that even a small emotion has you collapsed on the floor.

What triggers it?

It can be any emotion, but the most common trigger is humour – I have a friend who only needs to raise an eyebrow to have me on the floor. What's fascinating is that you retain consciousness throughout. You're in a crumpled heap on the floor, laughing your head off inside, but you just look asleep or dead. And then someone comes up and says, "Is he okay? Does he need an ambulance?". That's even funnier, and it keeps you under for a while longer. The attacks usually last only 10 or 20 seconds, but there's very little warning, and it can be exhausting. If you're collapsing 100 times a day, it can be an extremely disabling condition where you become fearful of leaving the isolated safety of your home.

What are the other symptoms?

Many people with narcolepsy also experience sleep paralysis and hallucinations when they're waking up or dropping off. It happens when the brain is in rapid

eye movement (REM), dreaming sleep, but you're awake, unable to move. The brain often manufactures petrifying visions. I used to see an axe murderer – I'd feel the axe as it slammed into my chest, and the blood trickling down my sides. Paradoxically, people with narcolepsy tend to experience fractured night-time sleep too, waking up as many as 20 or 30 times a night: it destroys your sleep quality.



What causes narcolepsy?

The vast majority of cases are caused by an infection such as flu or, as in my case, a streptococcal infection. The immune system destroys the invaders, but in some cases it also takes out a population of cells in the brain's hypothalamus that produce proteins called hypocretins, which play a crucial role in sleep regulation. At the moment, there's no cure, because once you've lost these cells they're gone. We're only able to treat the symptoms. There are stimulants such as modafinil and dexamphetamine that help to keep us alert, and small doses of antidepressants can treat the cataplexy. I've found drugs to control most of my symptoms, but I'm fortunate – not everyone responds to them.

How common is narcolepsy compared to other sleep disorders?

At any one time, chronic insomnia affects about 10 per cent of the population. Sleep apnoea is the other common one, which is when a person's breathing is interrupted during sleep – snoring is often a sign of this. Narcolepsy is a rarer disorder, affecting about 1 in 2,500. There are stories of people going 20, 30, even 60 years before being diagnosed, by which time the psychological damage can be serious. We still need to get much better at spotting these disorders.

Why is it so important to get good sleep?

Sleep is doing so many things for us: it's strengthening connections in the brain, making new ones, pruning ones we don't need. It's a time to replenish and recharge. Chronic sleep deprivation puts you at greater risk of a whole host of conditions: cancer, stroke, type 2 diabetes, depression, hypertension, obesity, the list goes on. It's no coincidence that every organism on Earth with any kind of neural cluster resembling a brain performs something akin to sleep.

Any top tips for a decent night's sleep?

This isn't going to be popular, but the most important thing you can do is stick to a routine. That means going to bed and waking up at the same time every day, even the weekend! For insomnia, my trick is to repeat a neutral word like 'the' over and over – not out loud, but in your mind. You'll find that your brain can't think about anything else, and racing thoughts will stop.

I've managed to get snatches of good sleep now for the first time in 20 years, and it's been so empowering. That's the upbeat revelation of this book – we really can change our sleep habits, even those of us with sleep disorders.



04

BEYOND BIONIC
CBBC, TUESDAYS, 4:30PM

WATCH MAN TAKE ON NATURE

Imagine being able to soar like a falcon or climb like a gecko. In new 13-part series *Beyond Bionic*, underwater explorer and all-round adventurer ANDY TORBET sets out to replicate nature's most extraordinary abilities. We asked him to reveal the five most difficult animal abilities to pull off

POMPEII WORM

The ability: Can withstand temperatures as high as 105°C.

The challenge: "I explore the science of heat resistance by attempting some firewalking, putting out a mock plane fire with the Manchester Airport fire service, and then, finally, by wearing a fireproof suit and standing inside a 'flambé tank' while a fireball rages around me."

JAPANESE SPIDER CRAB

The ability: Can live at depths of up to 600m.

The challenge: "I use what's essentially a wearable submarine to help me dive down to 600m. The suit keeps me at sea level pressure throughout, and its 'hands' look a bit like metal crab claws, so I'm given some dexterity tasks to do once I'm down there. I wanted to find out if I could be as functional as a crab at those depths."

OSTRICH

The ability: Can run at speeds of up to 69km/h (43mph).

The challenge: "I meet a man in California who's developed a kind of stilt-boot that uses rubber bands to mimic the ostrich's tendons, giving the wearer more spring in their step. We have a three-way race: me, him with his bionic boots, and an ostrich."

PEREGRINE FALCON

The ability: Can reach diving speeds of 389km/h (242mph).

The challenge: "I try to go faster than the falcon by strapping two electric jet engines to my thighs, jumping out of a plane at 4,500m (15,000 feet) and turning on my boosters. It's an augmented version of a sport called speed skydiving, where the aim is to achieve the fastest speed as you fall through the air."

GECKO

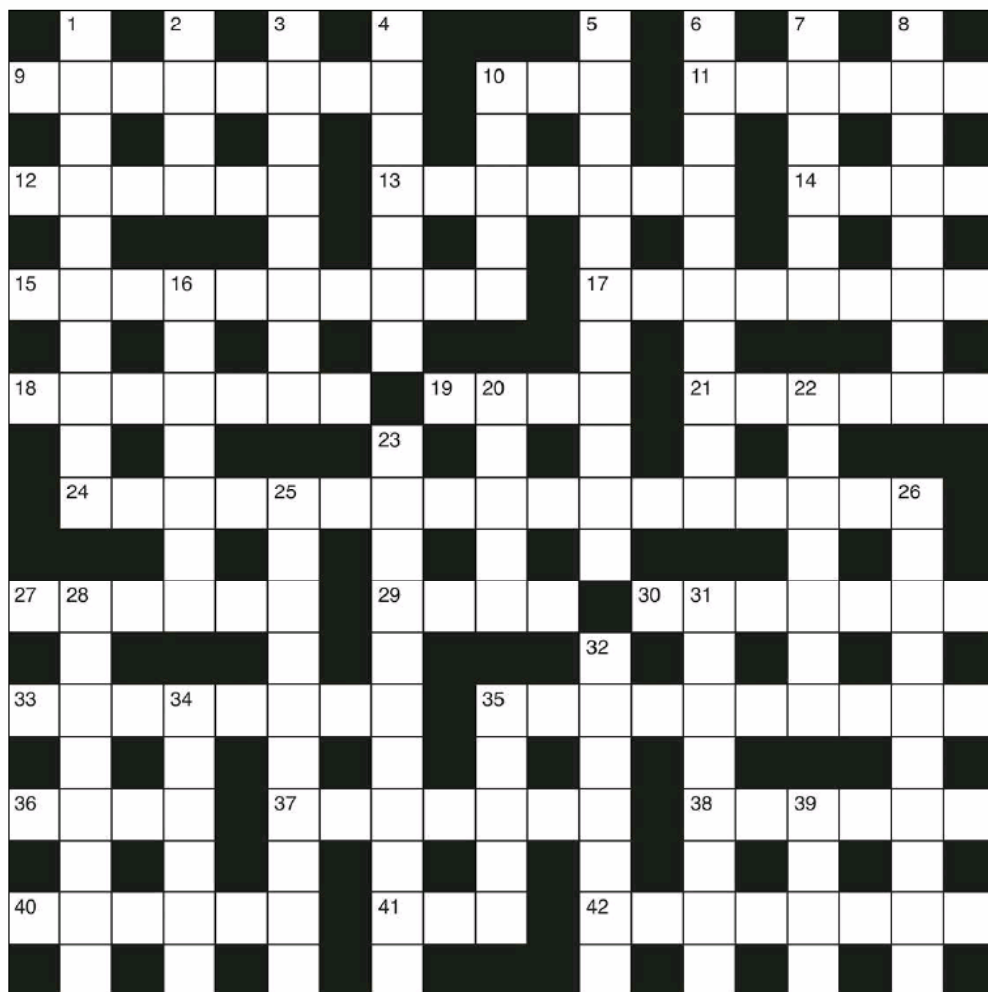
The ability: Can climb up walls and hang off ceilings.

The challenge: "I attempt to climb up a 10-storey glass building in Boston using a contraption that combines suckers and artificial gecko skin. The suckers use pistons to create a vacuum, while the gecko skin ensures there's a tight seal. It's the first time that this gadget has been tested on a real building."



BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



DOWN

- 1 Reactionary to encourage gas, say (6,4)
- 2 Phase pets out (4)
- 3 Save mild review for some islands (8)
- 4 Attempt to include old play (7)
- 5 Nectarine an alternative for old person (11)
- 6 General getting extra butter, for example (10)
- 7 Bigger bills, having a rodent (6)
- 8 A girl managed to get firm with a Roman general (8)
- 10 Clergyman is a supplier of chips, we hear (5)
- 16 Nowadays drone about being decorated (7)
- 20 Heard bit of quiet (5)
- 22 Drove thug to former capital (7)
- 23 Father joins politician when informant reveals ornamental growth (6,5)
- 25 Like a snake found in Hyde Park (10)
- 26 Correct to put fish at 90 degrees (5,5)
- 28 Part of France seen after quiche (8)
- 31 Finished with aristocrat getting decisive operation (8)
- 32 A bit worried about Sam cooking rice (7)
- 34 Garden ornament conceals European piece of heredity (6)
- 35 Deceptive move makes subtle sound (5)
- 39 Duplicate a child's bed (4)

ACROSS

- 9 Musical follows starting point of plant growth (4,4)
- 10 Payment for iron key (3)
- 11 Writer's third pen takes note of glacial episode (3,3)
- 12 Crustacean is to work too much (6)
- 13 Corn, to the French – that's inedible (7)
- 14 British impudence is a minor deviation (4)
- 15 Salad lover travels the country (2,8)
- 17 One plan revolved around old coin (8)
- 18 Spy worried after car examination (7)
- 19 Incentive to find short railway line (4)
- 21 Former spouse has a raw sort of secretion (6)
- 24 Capability, say, of painting new danger to queen (9,8)
- 27 German lied about registered plane (6)
- 29 Wish audibly for a victim (4)
- 30 District hides gold in branch (7)
- 33 Reporters have right to go back in advance (8)
- 35 Try fainter sort of profession (10)
- 36 Good time with a rural deity (4)
- 37 Element tribe used with hesitation (7)
- 38 Lucan ran off to find a gap (6)
- 40 No good returning moon changes to part of sundial (6)
- 41 Ready for collection of mathematical entities (3)
- 42 Wrong – I will have a pancake (8)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.



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Dr Zoe Williams

Trust Me, I'm A Doctor presenter, ex-Gladiator and fitness champion Dr Zoe Williams talks to Helen Pilcher

Zoe's Gladiator character, Amazon, was environmentally-friendly. She had a green outfit made entirely from sustainable materials.

Have you always wanted to be a doctor?

When I was three years old my Jamaican grandma bought me a children's doctor outfit. It came with a stethoscope. I put it on and I totally loved it. She asked if I wanted to be a midwife like her when I grew up. But I said, no, I want to be a doctor.

You're on telly a lot. Do you still get to be a GP?

I'm a GP first and foremost. I do two or three sessions a week. Then I do bits of TV – *Trust Me, I'm A Doctor*, *This Morning* and *Horizon*. I also work with Public Health England as 1 of 50 clinical champions for physical activity. It's a scheme that I helped set up and I'm really proud of it. My role involves training healthcare professionals about

physical activity. It's all about empowering patients to do what they can for their own health, rather than throwing medication at them.

How active are you?

On my GP days, I always cycle to work. Often in London, it's quicker to walk than take the tube, so I walk wherever I can. If I do travel by underground, I always take the stairs and I never use the elevators – it's not good for my reputation!

How did you become a TV Gladiator?

I originally applied to be a contestant. At the time, I was a junior doctor with a pretty big student loan to pay off and the cash prize was enticing. My friends encouraged me to go for it. When I passed the initial tests, they asked me back to audition as a Gladiator.

I couldn't believe it when they offered me the job as Amazon!

What was your favourite event?

I liked the giant cotton buds, but my favourite was Powerball where I had to tackle people. I used to play rugby, so I felt right at home.

What was it like being a Gladiator?

Amazing! We spent so much time together that we became close very quickly. We stayed in the same hotel when we were filming. We ate together. We were like one big happy family. I'm still good friends with a lot of the Gladiators now.

How do you unwind?

Recently, a friend bought me one of those mindfulness colouring books so you can sit down for a couple of hours and do colouring in. They're meant to help you de-stress. If I had time to sit down and colour in, I wouldn't be stressed in the first place! Exercise is my main way of unwinding. I go to the gym and do a full-on intense session.

If your life was turned into a film, who would you want to play you?

Beyoncé. She's smart, she's an amazing actress and she rocks an afro!

If you could get one message out there, what would it be?

I'd like to motivate people to find ways of incorporating physical activity into their lives. You don't have to go to the gym three times a week. It's about thinking about what you already do during your day and then finding ways to make it more active – things like taking the stairs, or cycling rather than driving to work. These things can become habits and over your lifetime they can make a big difference. 🧡

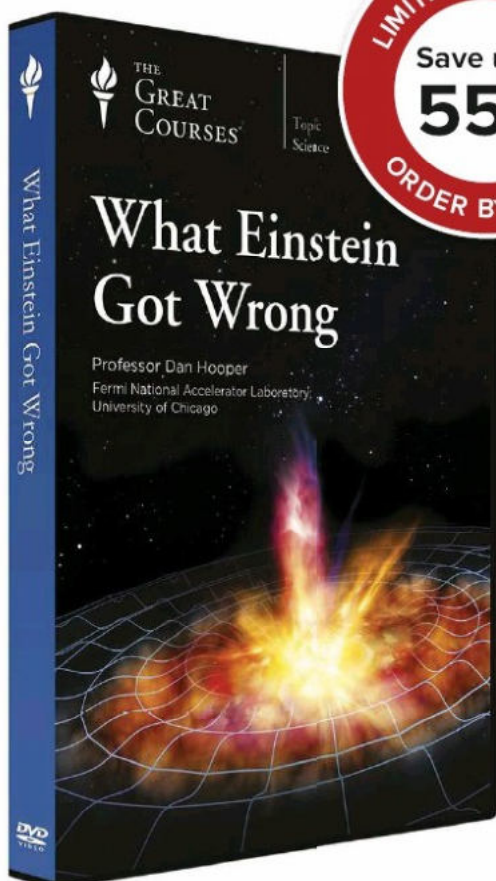
Dr Zoe Williams is a London-based GP and TV doctor.

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Trace Einstein's Path to Greatness—Missteps and All

Who has not heard of Einstein's theory of relativity, which revolutionized our understanding of space, time, and matter? He was *Time* magazine's Person of the Century, but even geniuses are not infallible. He rejected the possibility of black holes, and he was reluctant to accept the concept of an expanding universe or that gravity waves might exist. In other words, what Einstein got wrong includes some of the most exciting science of our time.

Physicist Dan Hooper of the Fermi National Accelerator Laboratory and the University of Chicago focuses on Einstein's major achievements, then covers his false starts, blind alleys, and outright blunders, which are fascinating for what they reveal about how science is done. More than just a biography of Einstein's life, this course provides you with an inside look at how this brilliant thinker arrived at his various revolutionary breakthroughs.

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A romantic couple is seen from behind, sitting on a large, light-colored rock. The woman, on the left, has long brown hair and is wearing a maroon bikini. The man, on the right, is shirtless and wearing blue and white striped swim trunks. They are both looking towards a cascading waterfall in the distance. The waterfall flows over dark, mossy rocks into a pool of water. The surrounding environment is a dense, lush tropical forest with vibrant green foliage and large trees. Sunlight filters through the canopy, creating a dappled light effect. In the upper right corner, the word "fiji" is written in a stylized white font, with the tagline "where happiness finds you" curved along its bottom.

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DIY SCIENCE

British Science Week launches on 9 March. To mark this incredible celebration of science, we've road-tested a selection of fun experiments for you to try at home – you can even get the kids involved as well!

WORDS: DR STUART FARRIMOND PHOTOGRAPHY: STEVE SAYERS/THE SECRET STUDIO



EXTRACT IRON FROM CEREAL

YOU WILL NEED:

- An iron-fortified breakfast cereal (make sure it's light in colour so you can see the iron – we used a crisped rice cereal and a multigrain cereal)
- Rare earth magnet (these are extremely strong magnets, usually made from neodymium)
- A large, sealable transparent food bag (a zip-lock style bag is ideal)
- A rolling pin and clean surface

From a young age we are taught that iron is a nutrient that makes us strong. It is a vital component of haemoglobin, which is the substance in red blood cells that carries oxygen.

Since the 1940s, breakfast cereals have been fortified with a variety of vitamins and minerals, and today they represent one of the key ways that children meet their daily iron requirements. This is

especially true for youngsters who otherwise have an unvaried and nutrient-poor diet.

Unlike iron that occurs naturally in meat and veg, the iron in cereals is added as a powder during production. Few people realise that it looks just like iron filings. Get hold of the strongest magnet you can find, then extract the iron from your cereal to see it with your own eyes.



SAFETY NOTES

Rare earth magnets are incredibly powerful. Do not swallow. Do not allow young children to play with them.

METHOD:

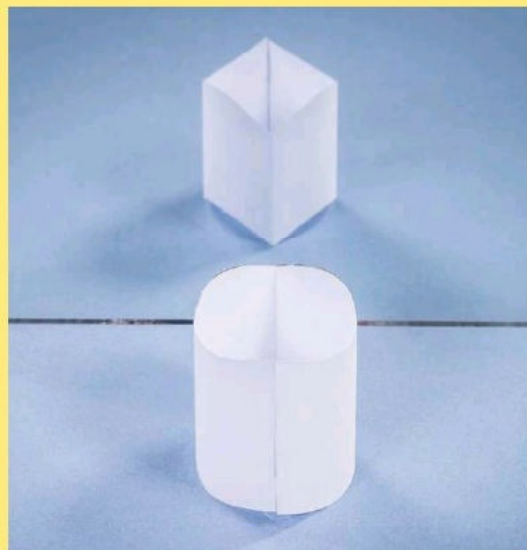
1. Pour dry breakfast cereal onto a surface and crush into a powder with a rolling pin.
2. Put your magnet into the cereal dust. Carefully lift the magnet and you should see that tiny pieces of cereal are gripping the magnet.
3. Pour one to two bowlfuls of breakfast cereal into a transparent food bag. If the cereal hasn't already been crushed, crunch it up with your hands. Pour in enough water to completely cover and saturate all the cereal.
4. Seal the bag and squash all the pieces until it is a smooth consistency, like thin soup. Put the magnet on the surface and place the bag on top. Agitate the bag so the cereal has a chance to be near the magnet. Leave it to rest for an hour.
5. Carefully lift the bag, taking care not to shake it, and raise the magnet to keep it touching the same spot on the bag. Look closely: you should now see a small patch of dark iron powder next to the magnet. Move the magnet across the surface of the bag to drag the iron particles around.



WHAT'S GOING ON?

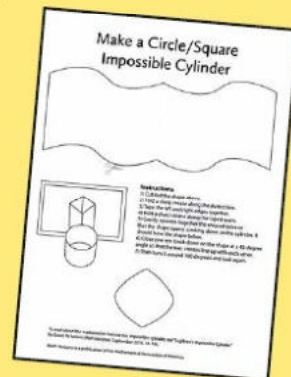
The iron that is added to breakfast cereal is just like the iron that goes into metal screws and nails, and is strongly attracted by a magnet. Grinding and crushing the cereal into a liquid mixture frees the added iron particles from the cereal matrix, allowing them to move towards to the magnet. Without fortification, many breakfast cereals would have little nutritional value. Cornflakes, for example, are milled, dried, toasted and squashed corn kernels with added sugar, salt and flavourings. They are devoid of most of the fibre and many other important nutrients that were originally present in the cereal seed. Furthermore, the milk that we pour onto cereal can have an inhibitory effect on how much of this precious nutrient can be taken in by the body. All of which goes to show the importance of a varied and balanced diet.

THE CYLINDER THAT IS SQUARE... THAT IS A CYLINDER



This 'ambiguous cylinder' optical illusion was devised by mathematician Kokichi Sugihara (bit.ly/29isMcS), earning him second place in the Best Illusion of The Year Contest 2016. If you place it on a table, and look down at a 45° angle, the object appears at first to be a cylinder. Rotate it 180° and it morphs into a open box shape. Place the same object in front of a mirror and it can be seen as both a cylinder and a box at the same time. There are no special effects in this illusion – it is a mere manipulation of the assumptions the brain makes.

When viewed from directly above, the actual shape of the object is neither a square nor a circle, but an intermediate of the two. The tops of two of its sides are curved downwards and the other two adjacent sides are curved upwards. This is an unusual shape that our brains are not used to seeing, and experience has trained our minds to assume that solid objects have flat surfaces and right-angled edges. Based on the data the brain is receiving, it concludes that it must be viewing a cylinder or a box. Even though we know the object can't be both, such is our predisposition to right angles that we are unable to see it for what it really is. Mathematician David Richeson has created a printable PDF template and instructions for the ambiguous cylinder – download it from bit.ly/ImpossCylTemplates



CREATE A BOTTLED CLOUD

YOU WILL NEED:

- A bike valve (we cut one out of an old inner tube)
- A bike pump (ideally a foot pump with pressure gauge)
- Surgical spirit or 90% isopropyl alcohol (rubbing alcohol)
- Hand drill (needs a drill bit with a similar diameter to the valve)
- Hot glue gun
- Empty plastic drinks bottle (minimum two-litre volume)
- Safety goggles

There is nothing mystical about clouds. In fact, it is perfectly possible to make your own cloud in a used drinks bottle. It might not be as massive as a 500,000kg white cumulus cloud, but at least you won't have to go paragliding to get up close and personal.

WHAT'S GOING ON?

As the Sun heats the ground, it warms the air above it, causing it to expand and rise. When rising moist air reaches an altitude of 600 to 900 metres, the water vapour in the air starts to cool and condense into tiny droplets. Each droplet then serves as a site where another droplet can easily form. Amalgamating into clusters that we know as clouds, these droplets scatter all frequencies of light to give them a white colour.

In our experiment, we coat the inside of a bottle with alcohol. We use alcohol because it evaporates faster than water, making it easier to get impressive results. When the bottle is sealed, it is quickly saturated with invisible alcohol vapour. Pumping air into the bottle increases both pressure and temperature. When the lid is opened, there is a sudden drop in pressure and temperature, which triggers airborne alcohol and water molecules to come together into liquid droplets – almost as if it had ascended by over 300m in a fraction of a second.



1. Carefully drill a hole in the lid of the plastic bottle that is just wide enough so that the valve will fit through.



2. Push the valve through the hole from the inside. It should be a tight fit. Fix valve in place with glue gun to make strong seal.



3. Pour a little rubbing alcohol/surgical spirit into the bottle. Now it's time to take this experiment outside!



4. Swirl the alcohol to coat the sides. Tightly screw on the lid. Attach bike pump to valve and put on your safety goggles.



5. Start pumping. Make sure bottle is not leaking air – if it is, add more glue. Pump to about 10psi. Do not overinflate.



6. Holding the bottle firmly, unscrew the lid, which may come off with a bang. And poof! A white cloud instantly appears!



SAFETY NOTES

Adults **MUST** carry out the cloud experiment. Children can watch.

Be careful with the drill and glue gun.

The bottle lid will undo with a lot of force. Hold tightly when unscrewing and point away from eyes.

Do not pressurise bottle to more than 10psi.

Wear safety goggles.

Do not consume chemicals. Wash hands after use.

VANISH THAT STAIN!

YOU WILL NEED:

- Clear plastic tumblers
- Iodine liquid or tincture (available online)
- Sodium thiosulphate powder or crystals (available online)
- Water
- Safety goggles
- Rubber gloves

WHAT'S GOING ON?

When mixed in water, iodine swims around as two iodine atoms bound tightly together. Iodine is blue-black in its solid form but when it is combined with water, the iodine pairs form loose links with water molecules, forming what are called charge-transfer complexes. These water-iodine complexes have a yellowy-brown colour. Sodium thiosulphate is known as a 'reducing agent' and it forces a negatively charged electron into the iodine duo, causing the iodine atoms to break apart as two negatively charged entities (called iodine ions). The separated iodine no

longer interacts with light and so the liquid loses all its colour.

This demonstrates how chemical stain removers remove stains by breaking apart the molecules that are causing the unwanted colouration. Colour-conveying molecules, termed chromophores, can often be torn asunder by either stripping them of an electron (oxidation) or by forcing them to accept an extra electron (reduction). Stain removers are either an oxidising or a reducing agent: household bleach is an example of an oxidising agent, while many carpet cleaners are reducing agents. As a very general rule, synthetic dyes, such as those in brightly coloured soft drinks, are broken apart by reducing agents, while naturally occurring dyes, like the pigments in red wine, are most vulnerable to an oxidising agent.



1. Put on safety goggles and rubber gloves. Put a tablespoon of sodium thiosulphate into the bottom of a tumbler. Half fill with water and stir to dissolve.



2. Add a few drops of iodine to the bottom of another tumbler, and half fill with water. Iodine stains, so protect hands and surfaces.



3. Carefully pour the sodium thiosulphate solution into the iodine. And voilà – the pigment will vanish!

GET ELECTRICITY FROM COINS

YOU WILL NEED:

- 10 2p coins
- Clear distilled vinegar
- Salt
- Paper towels
- Card
- Kitchen foil
- Two wires
- Crocodile clips (optional)
- LED
- Sticky tape
- Pen
- Dish

Building a working battery from scratch is within the reach of everyone. In fact, with a few basic items, you can make a working replica of the world's first modern battery, invented by Alessandro Volta way back in 1799.



WHAT'S GOING ON?

The same basic 'electrochemical' processes take place inside all batteries, including the one you've just made. All atoms are surrounded by a cloud of negatively charged particles called electrons. In the coin battery, each aluminium foil circle reacts with the acidic vinegar electrolyte to generate aluminium hydroxide on its surface along with an abundance of electrons. The excess electrons repel one another and escape from the metal along the wire. The moving electrons pass through the LED and round the circuit to the copper in the coins. The copper then serves to let the negative charge back into the electrolyte, thus replenishing the electrolyte and letting the reaction continue.

The oxygen that is dissolved in the electrolyte takes part in the electron transfer, and when it has been used up the electricity will stop flowing. Because there isn't a lot of electrolyte in your coin battery, it will quickly run out – so use your LED wisely!

METHOD:

1. Put coins into a bowl of vinegar, mixed with a little salt. Leave for a few minutes, then rub dry until shiny.

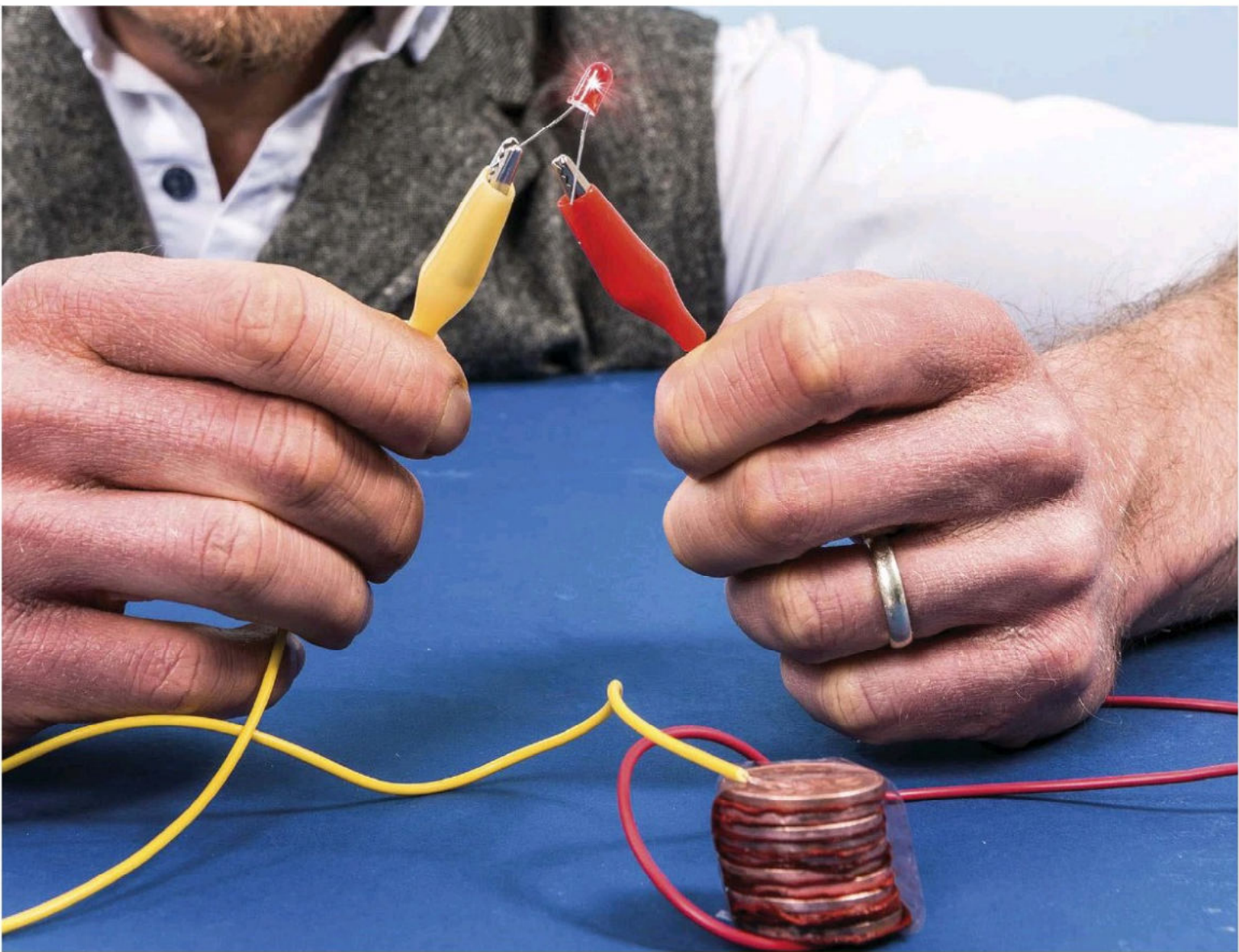
2. Using a 2p as a template, cut out nine card circles. Make nine foil circles – cut these a bit smaller. Soak the card circles in vinegar, mixed with a little salt.

3. Build up a stack in this order: coin, damp card circle, foil disc. Continue until you run out of coins. Make sure foil layers do not touch.

4. Take a wire and stick one end to the top coin surface. Take another wire and stick an end to the bottom coin surface. Add tape to secure the battery.

5. Connect the free ends of the wires to your LED.





DR STU'S QUICK KITCHEN EXPERIMENTS

SWEET DECEPTION



Pour five cups of tea. Add one teaspoon of sugar to the first cup, two teaspoons to the second cup and three teaspoons to the third. Add just one teaspoon of sugar along with a pinch of salt to the fourth cup. Leave the fifth cup unsweetened.

Mix up the order and ask someone to take a sip of each and arrange them in order of sweetness, asking them to guess how many teaspoons of sugar are in each. Most of the time, people say that the cup with sugar and a pinch of salt tastes as sweet as if it had three or four sugars! This is because salt increases the sensitivity of the sweet taste receptors in our taste buds – and also explains why food manufacturers add a little salt to sweets, cakes and biscuits.

MONSTER MALLOWES



Place a marshmallow on a microwavable plate and heat on full power for one minute. Watch as the marshmallow mutates into monstrous proportions! Leave it to cool down, then investigate your creation. Feel free to enjoy your – now gooey and fragile – sweet treat!

Modern marshmallows are made from sugar syrup, mixed with gelatine and whipped into a set aerated sweet. When heated, the gelatine network softens. At the same time, the air pressure inside each of the marshmallow's tiny bubbles increases. Gas molecules move faster at higher temperatures, so exert more force on the walls of the chamber they are within. The softened marshmallow bubbles therefore quickly expand.

MAKE SOME SEITAN



Tip a cup of high protein 'strong' flour (bread flour is ideal) into a mixing bowl. Add half to three-quarters of a cup of water and knead until a doughy ball forms. Hold under a running cold tap. Milky white liquid will

seep out of the dough as the starch is washed away. Keep squashing the ball to force the starchy liquid out. When the water runs clear, you have washed away most of the starch and will be holding a ball of gluten. Squeeze out any excess water and put it in a bowl or on a clean surface. You will discover just how sticky and elastic gluten really is! If you're feeling hungry, then why not add some flavourings and bake or fry it? Gluten prepared in such a way is known as 'seitan' and makes an excellent alternative to tofu.

MAKE YOUR OWN SLIME

YOU WILL NEED:

- PVA glue
- Bicarbonate of soda
- Contact lens solution (it must contain boric acid)
- Gel food colouring
- Glitter (optional)

Ghostbusters made green goop a must-have plaything more than 30 years ago. Now, slime is all the rage once more. This time, however, it can be made with items easily available in your local supermarket. Slime is great fun to play with, and its properties are underpinned by some serious science...

WHAT'S GOING ON?

The base ingredient for this slime recipe is PVA (polyvinyl acetate), which is made up of long, spaghetti-like molecules called polymers. The PVA molecules are surrounded by water that can slide past one another with ease.

The boric acid in the contact lens solution reacts with the bicarbonate of soda to create sodium tetraborate. These sodium tetraborate molecules form bridges between the PVA strands, preventing them from sliding past each other so easily. The more boric acid that is mixed in, the stiffer it becomes, and will gradually become a thick putty. If you get the proportions right you can achieve something that is a marvellous halfway house between a free-flowing liquid and an inflexible solid. If it doesn't work first time, keep experimenting with the quantities of the ingredients until you get marvellous, gooey slime! 🧪

SAFETY NOTES

Wash hands after making slime, and do not eat.
Slime might stain or damage some materials. Use a washable surface to make it.



1. Tip about 200ml of PVA glue into a large mixing bowl.



2. Add one teaspoon of bicarbonate of soda and thoroughly mix.



3. Add a few drops of food colouring, and glitter if you like. Stir well.



4. Gradually add one tablespoon of contact lens solution and stir. You may not need all the contact lens solution, so add slowly and stop when the slime starts to thicken.



5. Keep mixing until it starts to come away from the edges of the bowl, then turn out onto a clean work surface and knead until it reaches the desired consistency.

Dr Stuart

Farrimond is a science writer, presenter and educator, and hosts a regular segment on BBC Radio Wiltshire. His book *The Science Of Cooking* is out now.

DISCOVER MORE

Watch videos of some of our science experiments on our social media pages and on our website sciencefocus.com/diy-science